ROYAL SOCIETY OF NEW SOUTH WALES,

SYDNEY

PRESIDENTIAL ADDRESS

BY

THE PRESIDENT,

T. W. EDGEWORTH DAVID,

C.M.G., B.A., F.R.S., Hon. D.Sc. *Oxon.*

With Plates I, II, III.

MAY 3RD, 1911.

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PRESIDENTIAL ADDRESS.

By T. W. Edgeworth David, C.M.G., B.A. F.R.S., Hon. D.Sc. *Oxon.*

With Plates I, II.

[Delivered to the Royal Society of N. S. Wales, May 3, 1911.]

The privilege having once more been accorded me of addressing you as your President, I propose on this, the ninetieth anniversary of the existence of our Society, to touch briefly on the history of the Society during the last twelve months, then to offer some notes on the chief tectonic lines of Australia in particular and Australasia in general.

I—Royal Society of New South Wales.

The number of members on the roll on the 30th of April, 1911, was 315; 12 new members were elected during the past year. We have, however, lost by death two ordinary members and two honorary members, and nine by resignation. There is thus left a total of 316 members. This number, however, does not include the 14 honorary members. The losses by death were—Honorary Members, Sir William H[illegible]ggins[illegible]pper Tulse Hill, London, and Stanislao Cannizzaro, Rea[illegible]niversite, Rome. Ordinary Members, Dr. Walter Spencer and W. J. MacDonnell.

Dr. Walter Spencer, M.D. *Brux.*, was for fourteen years a member of our Society, and for seven years was a member of our Council, whose meetings he attended with great regularity. Dr. Spencer is probably best known to our scientific world as the President of the British Science Guild, a position which he occupied at the time of his death last year in Mexico City. He was most enthusiastic in his devotion to the work of that body, and was chiefly instrumental in moving the Government of this State to provide

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increased ground space for the recreation of children, especially school children. His efforts at securing better methods for the carriage of stock for our Sydney Meat Supply further proves how near was the health and general welfare of the community to his heart. Throughout the whole of his life amongst us he proved himself to be a most conscientious and sympathetic worker in the cause of humanity no less than in that of science.

WM. JOHN MACDONNELL, Fellow of the Royal Astronomical Society, was a member of our Society for forty-two years. An active member of the British Astronomical Association he was president for two years and secretary of the New South Wales Branch for several years, occupying that post when he died. He was a most enthusiastic amateur astronomer. His memory was remarkable, he could quote volume and almost page for hundreds of articles which he had read in the *English Mechanic*. Years ago when the Royal Society had an astronomical section, he was at that time one of its most active members. He participated in one of the Transit of Venus Expeditions. He was also a keen numismatist, making a specialty of Greek coins.

In regard to our Library it may be stated that books and periodicals have been purchased this year at a cost of £41 13s. 7d. A great number of unbound books and periodicals are about and will continue to be bound in a cheap style of binding in order to make them accessible to the members.

The number of Institutions on the exchange list numbers 429, and the publications received in exchange for the Society's Journal and Proceedings during the year were 222 volumes, 1815 parts, 161 reports, 282 pamphlets, and 20 maps, making a total of 2,500.

During the past year the Society held eight meetings at which 32 papers were read, the average attendance of the members being 34.

The following is a list of the series of Popular Science Lectures, illustrated by lantern slides etc., and of the Lecturers during 1910:—"The Velocity of Chemical Changes," by Professor Fawsitt, D.Sc., F.C.S.; "Early Blue Mountain Exploration, (Barallier's furthest West) by Mr. R. W. Cambage, L.S.; "The Mountains of New South Wales, their nature and origin," by Mr. C. A. Süssmilch, F.G.S.; "Modern Methods of Recording Earthquakes," by Rev. E. F. Pigot, B.A., M.B., S.J.; "The Social View of Capital," (two lectures), by Mr. R. F. Irvine, M.A. The excellent attendance at these lectures, and the enthusiastic way in which they were received is proof of their usefulness, and the hearty thanks of our Society are due to the lecturers who have so unselfishly placed their services at the disposal of our Society for the sake of the advancement of science.

May I also on your behalf and my own, express on this occasion, our deep gratitude to the Hon. Secretaries, Mr. J. H. Maiden, F.L.S., and Mr. F. B. Guthrie, F.I.C., as well as to the Hon. Treasurer, Mr. David Carment, F.I.A., for their unremitting and generous services in the best interests of our Society. It is satisfactory to note that the finances of the Society are sound.

On the occasion of my recent visit to England, it was my privilege on several occasions to meet our old colleague, whom we have all come to look upon as a second founder of this Society, Professor Liversidge, and members will be pleased to hear that he is in excellent health and engaged in active research on lines made familiar to us by so many of his papers published in our journal. He desired me to convey his kindly greetings to all the members, greetings which, I am confident we all heartily reciprocate.

It was obvious that he had played an important part together with Professor Masson of Melbourne, Professor Martin of the Lister Research Institute, R. Threlfall (late

Professor of Physics at the University of Sydney) Professor J. P. Hill and others of our former colleagues in so successfully pressing the invitation of the science bodies of Australia to the British Association for the Advancement of Science to come over and visit us in 1914. It was also obvious from the names mentioned of the intending visitors that the British Association would be well and worthily represented on what we all hope will be a happy and helpful meeting between the old world and the new.

II—Notes on some of the Chief Tectonic Lines of Australia.

The relief model of Australia reproduced on *Plate 1*, and the lines of section which accompany it, represent some of the chief structural trend lines which have presented themselves to one's notice up to the present. Suess in his magnificent and monumental work, "Das Antlitz der Erde," has already furnished a masterly sketch of some of the main trend lines of Australasia.[1]

The late Captain F. W. Hutton, F.R.S., has furnished an excellent and succint account of the chief structural features of New Zealand.[2] The Horn Expedition to Central Australia threw much light on its dominant trend lines.[3] In 1893, in a Presidential Address to the Linnean Society, I attempted to sketch from somewhat meagre data the then state of our knowledge of the leading trend lines of Australia.[4] Professor Gregory, F.R.S., has indicated some of the chief trend lines of Victoria.[5] Mr. W. H. Twelvetrees, F.G.S., the Government Geologist of Tasmania and

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[1] Suess, The Face of the Earth, Translation by Hertha, B. C. Sollas and W. J. Sollas, Vol. II, pp. 149 – 164; and Vol. IV, pp. 301 - 321 and 501.

[2] Q.J.G.S., May, 1885, Sketch of the Geology of New Zealand, by Capt. F. W. Hutton, F.G.S., pp. 191 - 220, figs. 1 – 4.

[3] Report of the Horn Exploring Expedition in Central Australia, Geology by Prof. Ralph Tate and J. A. Watt, B.A., B.Sc., pt. 3, pp. 1 – 81

[4] Proc. Linn. Soc., 1894, Vol. VIII, Ser. 2, pp. 540 - 607, pls. xxvii, xxviii.

[5] Geography of Victoria, Whitcombe and Tombs. By Professor J. W. Gregory, F.R.S.

Mr. G. A. Waller have done similar work for Tasmania.[1] Still more recently Mr. E. C. Andrews,[2] Mr. C. A. Süssmilch,[3] and Mr. C. Hedley,[4] have dealt with the physiography, epeirogenic uplifts, disjunctive lines, and warping of New South Wales. In a later paper Mr. E. C. Andrews[5] has summed up our knowledge of recent and Tertiary earth movements in Eastern Australia and Tasmania. Mr. Walter Howchin, F.G.S.,[6] has greatly added to our knowledge of the tectonic lines of South Australia. Mr. A. Gibb Maitland, F.G.S., the Government Geologist of South Australia, has summed up a vast amount of information obtained by himself and the officers of his survey on the geological structure of West Australia in his presidential address to the Australasian Association for the Advancement of Science,[7] and aiso in his recent paper on "The Foundation Stones of West Australia." He has also contributed for my present address a valuable note on the chief lines of fault traversing that State. In regard to Queensland. nearly all our knowledge of its structural features are contained in the reports of the Geological Survey, notably those by Dr. R. L. Jack, F.G.S., Messrs. W. H. Rands, F.G.S., and B. Dunstan, F.G.S. For the structure of Northern Territory the chief information is given in the official reports by Mr. H. Y. L. Brown, A.R.S.M. F.G.S., Government Geologist of South Australia, and by his assistant Mr. Basedow, B. Sc. [8]

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[1] Report Austr. Assoc. Adv. Sci., Dunedin, 1904, pp. 613, 622 – 629.

[2] Physical Geography of New South Wales. by E. C. Andrews, B.A., pp. 55 – 94.

[3] This Journal, Vol. XLIII, 1909, pp. 331 - 354, pls. ix – xiv.

[4] Proc. Linn. Soc. N. S. Wales, Presidential Address, Vol XXXV, 1910 and *ibidem* Vol. XXXVI, pp. 9 – 21, pls. i, ii.

[5] This Journal, Vol. XLIV, pp. 420 – 480, figs. 1, 2, The Physiographic Unity of Eastern Australia, by E C. Andrews, B A.

[6] The Geography of South Australia, by Walter Howchin, F.G.S., edited by Professor J. W. Gregory, 1909; also see Howchin, Journ. Roy. Soc. S. Australia, Vol. XXVIII, pp. 253 – 280, pls. xxxvii – xliv, and Vol. XXX, pp. 227 - 262, pl. xii; also Q.J.G.S., Vol. LXIV, pp. 234 - 258, pls. xix – xxvi.

[7] Report Austr. Assoc. Advt. Sci., Adelaide, 1907, Presidential Address by H. Gibb Maitland, F.G.S., pp. 131 - 137.

[8] Report on the Geology of Northern Territory, By Authority. Adelaide 1895 and 1906.

It may be added that in the matter of late epeirogenic uplifts of Australia much light has been shed by the palæontological researches of Messrs. R. Etheridge and W. S. Dun; and new and promising line of investigation bearing on recent movements of the East Australian coast line based on the present distribution of our forest trees in relation to soils and geological formations has been instituted by Mr. R. H. Cambage, L.S.[1]

The excellent seismograph records now being published from time to time by the Rev. E. F. Pigot, S.J., from the Seismograph Observatory at St. Ignatius College, Riverview are yielding invaluable information as to the areas of modern re-adjustment of the earth's crust in the neighbourhood of Australia. Other references will be given in their proper place throughout this address.

The relief map of Australia and Tasmania reproduced on *Plate 1*, was specially prepared for this address by Mr. W. K. McIntyre of Sydney University, from data generously placed at our disposal by Mr. H. E. C. Robinson, to whom Australian cartography is very deeply indebted. In this relief map the following features at once arrest attention: (1) The strongly marked eastern ranges approaching so closely to the coast near Cape Howe and in the neighbourhood of Hinchinbrook Island and the Bellenden-Ker Ranges. (2) The broad basin lying to their west extending from the Gulf of Carpentaria to the Australian Bight with the eastern branch of the Darling-Murray Basin, and the immense western extension around the head of the Great Australian Bight as far west as Cape Arid. The boundary on the south of the Darling-Murray Basin introduces us to a new tectonic element, (3) The Victorian Main Divide in which an east to west line of warping or uplift has dominated the older meridional lines, an uplift which is complementary to the inthrow of the parallel and adjacent structure of (4) Bass Strait. The boundary of the Darling-Murray Basin on the west reveals element (5), the great fork of the Mount Lofty and Flinders Ranges thrust far north into the great basin. The deep indents of St. Vincent and Spencers Gulfs and the basins of Lakes Torrens and Eyre, suggest strong tectonic disturbances extending from here towards the Gulf of Carpentaria.

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[1] Report Austr. Assoc. Adv. Sci., Vol. xi, pp. 473 - 483.

The main western boundary of the Great Basin is (6) the plateau of Central Australia, Northern Territory and West Australia, accentuated at its eastern edge by the strong east and west trend lines of the MacDonnell and Musgrave Ranges, and terminating south-westwards in the Darling Range peneplain, interrupted by the bold bluffs of the Stirling Range. The western boundary of the Darling Range is followed further west by what Mr. Gibb Maitland has shown to be one of the most remarkable tectonic features of Australia, a deep, long and narrow rift valley. Cape Leeuwin and Cape Naturaliste lie on the west side of this valley, the deep indent between Cape Naturaliste and Bunbury being due to this tectonic feature. I cannot do better than here quote Mr. A. Gibb Maitland's account of this feature as well as on other fault lines in West Australia: "In the short time available it has been found quite impossible to wade through the forty-one bulletins and fifteen annual reports of the Geological Survey. The following however, are the more important main fault lines, so far as is known :—1. The face of the Darling Range from the South Coast to somewhere about Mingiew (S. Lat. 29 – 34°) appears to be marked by a major fault, which there is some reason for believing marks the eastern wall of a long "rift valley," of which probably part of the western wall is to be found in that narrow ridge of ancient crystalline rocks from Flinders to Geographe Bay. The fundamental rocks of the islands of Rottnest and Houtmens Abrolhos possibly mark the northward extension of these latter. The eastern fault which forms the escarpment of the range brings the palaeozoic and newer rocks in juxtaposition to the ancient crystalline schists, which are believed to be of Archaean Age. The sedimentary rocks which fill this "rift valley" are so arranged that there is a gradually ascending series southwards from the Irwin River Coal Field. Cretaceous rocks outcrop at Gin Gin, they have been met with in some of the bores in the metropolitan area, beneath Perth, and also rise to the surface to the southward along the coastal plain. The most recent beds in this "rift valley" make their appearance near Bunbury, and are associated with more or less horizontal sheets of basalt, these latter outcrop at Bunbury, at several places in the bed of the Blackwood and the south coast between Cape Leeuwin and Cape D'Entrecasteaux, they have also been met with in a bore put down in the valley of the Donnelly River. There seem reasons for believing these to be contemporaneous with the bedded basalts of South Australia and Victoria, if so then it is very likely that this fault is Late or Post Tertiary.

"2. On the Warrawoona Field, Pilbarra Gold Field, (Bull. 40, plate 10, of reprint of Bulls. 15, 20, and 23) a very marked fault at least six miles in length, traverses the field in a N.W. and S.E. direction, and probably extends far beyond the limits of the area mapped. The fault hades to the N.E. at about 60 degrees. A glance at the map shews several bands of quartzite disposed somewhat in the shape of a fan, the ribs of which open out gradually to the west. The peculiar mode of occurrence, and ending off of these beds is strongly suggestive of this line marking an important fault, which, however, makes no show at all on the surface. Further evidence of this hypothesis is to be found in the fact that the continuity of the newest diabase dykes, which cross the field in a direction about north-east and south-west, is very materially affected. Many of the rocks are sheared, and the quartz reefs folded and overthrust, all of which points to this being a region of great dynamic movement.

"3. The Warrawoona belt extends northwards fifteen miles to Marble Bar, which field is also traversed by at least four major faults, which have a general northerly strike. These faults have played great havoc with the newer diabase dykes, as may be seen by an inspection of the geological map (pl. 14, Bull. 40). Of the age of the faulting both here and at Warrawoona, there is no direct evidence, other than that it is younger than that of the newest diabase dykes, of whatever age they may be.

"4. The Collie Coal Field is bounded by two faults trending generally north-west and south-east. The faults are of considerable horizontal extent as well as of great downthrow. I am rather inclined to regard the boundaries of the great Stirling Range, as marking the extension of the Collie group of faults."

The trend and positions of these lines of faults are shown on *Plate 2*, and the rift valley and the folds in the adjacent peneplain are shown in figure 1.

FIG. I. DIAGRAMMATIC SECTION ACROSS THE GREAT TROUGH FAULT OF WEST AUSTRALIA. from data suggested by A. Gibb-Maitland F.G.S. Vertical Scale 8.000 feet to an inch.

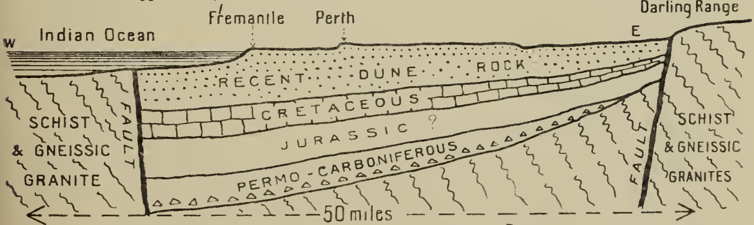
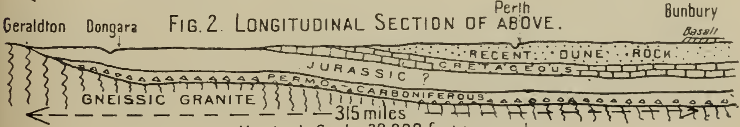


FIG. 2. LONGITUDINAL SECTION OF ABOVE.



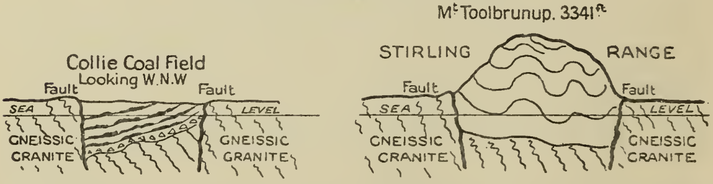
Vertical Scale 20.000 feet to an inch

As already stated by Mr. Maitland, the faults bounding the Collie Coal-field[1] are probably continuous with those which have given origin to the Stirling Range.[2] Mr. Maitland states in regard to the Stirling Range that lateral compression has worked from the south, and has formed three anticlines in a distance of ten miles. Mount Toolbrunup, the highest point in the range is nearly 4,000 feet above sea level. A prolongation of these faults to the E.S.E. runs through Cape Riche. The southern of these two faults, or perhaps zone of faults, has a throw of approximately the order of 2,000 feet.

In regard to the rift valley of the west coast, the sharp trend northwards of the Murchison River close to its mouth, and the remarkable coastal indents near Shark Bay are very suggestive of a prolongation of this rift valley in that direction. The probable geological structure of this rift valley are shown on Figs. 1 and 2, and that of the Collie-Stirling fault zone on Fig. 3.

FIG 3. DIAGRAMMATIC SECTIONS ACROSS COLLIE-STIRLING TROUGH

Vertical Scale 8000 feet to an inch



In addition to the evidence of the faults, the trend lines of West Australia are indicated by:—

(1) Prevalent strikes of folds in sedimentary rocks.

(2) The trend of the metalliferous (especially auriferous) belts.

(3) The direction of the foliation and schistose structure in the gneisses and schists.

(4) The trend of the banded jaspers and hornstones.

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[1] Permo-Carboniferous. [2] Older Palæozoic.

(5) The prevalent strike of the long axes of masses of eruptive rocks such as granite, quartz-porphyry, diabase, dolerite, etc.
(6) Prevalent strike of quartz reefs.
(7) Trend of joints in rocks.
(8) Trend of rivers and lakes.

The banded jaspers and hornstones are such a conspicuous feature in the geology of West Australia, and so wonderfully persistent for distances of hundreds of miles, that they deserve special mention here.

At Northampton in West Australia, there is a great development of what Mr. Maitland has termed sheeted zones of micaceous and garnetiferous granulite, traversed by much puckered and contorted veins of quartz. "These sheeted zones trend generally north-west and south-east. These are not planes of bedding, but they represent gliding planes, along which the rocks have yielded to the irresistable lateral pressure, resulting, *inter alia*, from the contraction of the earth's crust. The result of this lateral earth creep is that many of the rocks have been milled down, as it were, and in some cases rocks having all the external characters of finely banded slates or schist have resulted. An excellent instance of this occurs in the valley of the Helena River where the normal granite as a result of the operations of the great earth mill has been ground to powder or rock flour, producing a rock termed mylonite."

That the mylonites represented by the banded red jaspers and hornstones have been subject to earth movements since their formation is proved by the fact mentioned by Mr. Maitland, that at Boogardie and on the Murchison field, as well as at Tuckanadra, 26 miles N.E. of Cue, they have been thrown into a series of gentle curves. They are crossed by numerous faults almost at right angles, and pockets of gold ore occur at the intersection.

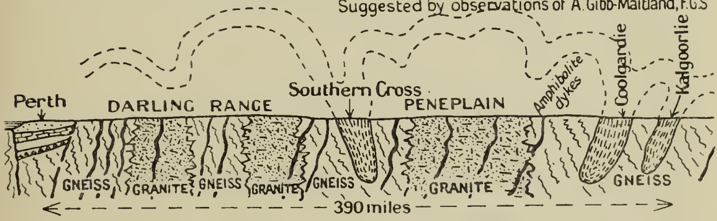
As regards prevalent strikes of folds in the sedimentary rocks and schistose structure in the gneisses and schists at the Porongorup Range near Albany, the massive gneisses are foliated in a direction N.W. to S.E. This trend is fairly constant amongst the older crystalline rocks of the southern part of West Australia, The three anticlines of the Stirling Range strike approximately parallel to the major faults which bound that range, the general trend being from W.N.W. to E.S.E. Mr. Maitland considers that the folding force has in this case operated from the south northwards. Further north, as in the Coolgardie and Kalgoorlie goldfields, the strike of the foliation and bedding is more meridional being about N.N.W. and S.S.E.

At Northam the trend of gneissic foliation is N.W. to S.E., while that of the quartz-dolerite or quartz-diabase dykes is chiefly from S.W. to N.E. From the Murchison through Cue to Leonora, the trend lines in the older rocks are still a little W. of N. and E. of S.

The same remark applies to the great auriferous belts. According to Mr. Maitland's views, these consist of highly inclined metamorphic and sedimentary rocks associated with contemporaneous interbedded eruptive rocks. Some of these are distinctly amygdaloidal, and there is every reason to believe them to be ancient lava flows. These, in Mr. Maitland's opinion, have been infolded in great synclines, amongst the gneisses, and have been subsequently intruded by newer rocks such as serpentines, quartz-dolerites (quartz-diabase), acid-porphyries, and granites, the last intersected still later by greenstone dykes.

According to Mr. Maitland's view the great gold belts of Western Australia would therefore present some such an appearance as is shown diagrammatically on Fig. 4. The other alternative seems to be to regard these belts as overthrust, rather than as overfolded areas. There can be little doubt that both overfolding and overthrusting are present.

FIG. 4. Sketch roughly diagrammatic from Perth to Kalgoorlie.


Suggested by observations of A. Gibb-Maitland, F.G.S

As the Pilbara region is approached, all the trend lines, as shown on *Plate 2*, swing from the nearly meridional once more into a N.W. and S.E. direction. This trend is well shown in the directions of the Ashburton, Fortescue, and De Grey Rivers, as well as in the trend of ranges like the Hammerley Range and the Throssell Range.

The Doolena Gorge, "the gateway of the north-west," and the Bangemall Anticline both have a N.W. to S.E. trend. The S.W. limb of this large anticline is steeper than the N.E. line, which suggests that the overfolding in this case came from the N.E. The fold 'pitches' to the S.E., which suggests that the earth-movement was more intense towards the N.W. At Warrawoona the newer dolerite dykes intersect the older folded rocks in enormous numbers. Their dominant strike is from S.W. to N.E., as in the case of the Northam dykes.

In the Kimberley district of West Australia, Mr. E. T. Hardman[1] has described Pre-Cambrian, Cambrian, Devonian and Carboniferous Rocks. Mr. H. P. Woodward[2] has also described part of this area, as well as Dr. R. L. Jack, LL.D., F.G.S.[3] Their observations show that the schists, gneisses, and banded jaspers strike in a N.W. direction through the King Leopold Range to King's Sound. This belt of metamorphic rocks is 10 to 30 miles wide and 120 miles in length. The Devonian rocks in the central and eastern part of the Kimberley region have been folded in broad open folds on axes which trend in a N. E. and S. W. direction. The Carboniferous (Permo-Carboniferous Rocks) have not been folded, but merely tilted.

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[1] Report on the Geology of the Kimberley District, by E. T. Hardman By authority, Perth, 1884.

[2] Report on the Gold-fields of the Kimberley District, by H. P. Woodward. By authority, Perth, 1891.

[3] Bull. Geol. Survey, West Australia, No. 25, pp. 1–46.

In regard to the Devonian rocks of the Kimberley district Mr. Hardman estimated their thickness at nearly 11,000 feet, and Mr. H. P. Woodward describes these Devonian rocks as striking N.E. and S.W. The question that obviously here suggests itself, is do these fold troughs of the central and eastern part of Kimberley, such as those of the Carr-Boyd Ranges, Saw Ranges and Lubbock Range meet Pre-Cambrian folds of the King Leopold Range in linking or in syntaxis. These trend lines from S.W. to N.E. agree in general direction with the folding of the Devonian Rocks of the Burdekin district as well as with one of the two directions of folding on the Gilbert Gold-field of Queensland. From a letter received from Mr. Gibb Maitland it would appear probable that these two directions of folding at Kimberley in West Australia form part of a syntactic arc, and they may therefore provisionally be grouped as such. At present the evidence as to the folds being symmetrical or asymmetrical in this region is insufficient. One cannot therefore as yet arrive at a definite conclusion as to the sense in which the folding force has operated.

That we know so much already about the structure lines of West Australia, more probably than we know about those of any of the other States of the Commonwealth, is due chiefly to the enthusiastic and sustained efforts of Mr. A. Gibb Maitland and his colleagues, notably Mr. H. P. Woodward, Mr. E. T. Hardman and others who have toiled so hard and so long in a country where travel bristles with dangers and difficulties.

If now we turn to South Australia we find that most interesting features have lately come to light. The early report by A. R. C. Selwyn[1] revealed a rough plan of the build of the Mount Lofty Ranges. The numerous records and reports by Mr. H. Y. L. Brown, Assoc. R..S.M.,[2] contain much information as to trend lines at intervals over this vast territory, and still more important information is afforded by his geological map of South Australia. The Horn Exploring Expedition to Central Australia elucidated the chief tectonic features of the MacDonnell Ranges.[3] Mr. H. Basedow has published useful information as to the trend lines of the Musgrave, Mann, Everard, and Ayers Ranges.[4] Dr. W. G. Woolnough[5] has contributed a paper, chiefly petrological, on the Mount Lofty Ranges. Dr. Douglas Mawson, B.E., D.Sc.,[6] has dealt with the structure of the north-eastern virgation of the Mount Lofty Range where it spreads away into the Barrier Ranges. Of late years a flood of light has been thrown on the obscure questions of the trend lines of South Australia by Mr. Walter Howchin.[7]

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[1] Geological Notes of a Journey in South Australia from Cape Jervis to Mount Serle. Parl. Paper No. 20, Adelaide, 1859.

[2] Chiefly on the mining fields of South Australia and Northern Territory, published by the Mines Department of South Australia or as Parliamentary Papers.

[3] Horn Scientific Expedition to Central Australia. Report on the Geology by Professor Tate and J. A. Watt, M.A., B.Sc.

[4] Trans. and Proc. Roy. Soc. S.A., Vol. xxix, pp. 57 – 102, pls. xiii – xx.

[5] Trans. and Proc. Roy. Soc. S.A., Vol. xxxii, pp. 121 – 137, pls. i, ii.

[6] Thesis for D.Sc. Degree presented to the University of Adelaide, 1909-10.

[7] Trans. and Proc. Roy. Soc. S.A., Vol. xxviii, (1904), pp. 253 – 280. pls. xxxvii – xliv; *Ibid.*, Vol. xxx, (1906) p. 227. Rep. Austr. Ass. Adv, Sci., Vol. xi, p. 114. The Geography of South Australia including the Northern Territory, by Walter Howchin, F.G.S., and Professor J. W. Gregory, D. Sc., F.R.S. Q.J.G.S., Vol. LXIV, 1908 pp. 234 – 258, by Walter Howchin.

In his introduction to Mr. Howchin's Geography of South Australia, Professor Gregory contends that (*op. cit.*, p. 25 26, fig. 6) there is evidence of two distinct groups of folds in South Australia, differing in date of birth as well as in direction. The older group has dominant E. and W. trends, the newer according to Gregory, have a nearly meridional trend inclining slightly to W. of N. His conclusions are evidently based on the observations of Mr. Howchin (*op. cit.*, pp. 77–92). This very important problem will be discussed presently.

Reference to the relief map, *re* South Australia, makes it clear that the most conspicuous tectonic feature is that of the depressed area in which lie Lakes Eyre and Torrens prolonged southwards into the subsidence regions of Spencer's Gulf and St. Vincent's Gulf, and bounded eastwards by the western escarpment of the Mount Lofty and Flinders Ranges. Westwards the depressed area is bounded by the eastern edge of the great plateau of Central Australia near the west shores of Lake Torrens. If we refer to the map on *Plate 2*, commencing at Kangaroo Island and trace the lines of fold northwards, we cannot fail to be struck with the evidence of either a gradual change in the trend of the fold lines, or of the existence of two different groups of folds as argued by Mr. Howchin and Professor Gregory. The geological map is strongly in favour of a virgation and general meeting of the trend lines in syntactic arcs from Kangaroo Island to the Mount Lofty Ranges, and from the Mount Lofty Ranges to the Barrier Ranges. Dr. Woolnough in the paper just quoted, argues that the crystalline rocks on the eastern side of the Mount Lofty Ranges represent folded Pre-Cambrian rocks, the trend of whose folds agrees approximately with the later folds of the Cambrian strata. Mr. Howchin on the other hand holds that these crystalline rocks of the eastern Mount

Lofty Ranges represent Cambrian strata which have experienced intense contact metamorphism as the result of the intrusion of large contiguous belts of granite.

Mr. Howchin, at the same time, has recorded the existence of Pre-Cambrian rocks in the neighbourhood of Aldgate in the Mount Lofty Ranges, where their general trend lines, as far as they can be seen, correspond with those of the overlying Cambrian rocks. Certainly the Cambrian cleavages and joint planes pass directly downwards into those of the Pre-Cambrian.

Mr. W. N. Benson, B.Sc.[1] states (*op. cit.*, p. 107) that "in each of the three periods of great earth-movements evidenced in the Mount Lofty Ranges, viz. (1) the Pre-Cambrian, (2) the older Palæozoic Post-Cambrian, (3) the late Tertiary, the axis of folding or faulting was almost a meridional one. From Yankalilla to Aldgate, in the southern part of the Mount Lofty Ranges there appears to be an approximate agreement in direction between the Pre-Cambrian and older Palæozoic Post Cambrian folding. At the same time it is generally admitted that there is a strong unconformity between these two groups of rocks."

Again in Yorke Peninsula, near the Parara Mine, west of Ardrossan, Mr. Otto Tepper[2] shows that there is no great divergence between the strike of foliation there of the schists of Pre-Cambrian age and that of the Lower Cambrian limestone. He gives the strike of these Pre-Cambrian strata as N. 5° W.,[3] at the Parara Mine, and N. 8° E. at Mooloowurtie, the dip of the foliation at the Parara

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[1] Trans. Roy. Soc. S. Australia, Vol. XXXIII, 1909, Petrographical Notes on Certain Pre-Cambrian rocks of the Mount Lofty Ranges, with special reference to the Geology of the Houghton District, pp. 101 - 140, pls. i - v.

[2] Trans. Phil. Soc. Adelaide, 1877-8, pp. 71 – 79, Cliffs and Rocks at Ardrossan, Yorke Peninsula.

[3] The bearings given from here to the end of the paper are magnetic, except in the case of the bearings relating to West Australian areas. The latter bearings are true.

Mine he gives as from about 60° to 70° easterly. The lower Cambrian rocks when traced northwards from Mount Lofty and eastwards into the Barrier Range district of New South Wales show, near Poolamacca a strike of N. 10° W. (magnetic) to N. 20° W., has been observed by me at Campbell's Creek in that vicinity, the dip being easterly at about 70°. At Torrowangie the lower Cambrian limestone (probable equivalent of the Brighton limestone near Adelaide) dips E. 15° N. at about 13° up to 20°. At Paps Creek about 32 miles northerly from Broken Hill, near the locality of Campbell's Creek above referred to, Dr. Mawson has observed an unconformable junction between the lower Cambrian system and a group of schists (talc and mica schists) immediately to their west. There can be little doubt that these schists are Pre-Cambrian.

The authors of the geology of the Broken Hill lode[1] point out that there is a divergence of strike between that of the schists and that of the Cambrian strata at Paps Creek of from 25° to 33°. These talc or mica schists although Pre-Cambrian may not be Archæan. Now at Broken Hill, only 32 miles to the south, the true Archæan gneiss and amphibolite schists strike about E. 40° N., and have been strongly overfolded as well as overthrust in a south easterly direction. There is thus a wide divergence between the trend of the folia of these Archæan rocks of Broken Hill and the strike of the lower Cambrian glacial beds and limestones near Campbell's Creek and Torrowangie, the divergence amounting in this case to about 60°. But there is also a divergence between the trend of the Broken Hill Archæans and that of the Paps Creek schists. Possibly the latter may be Algonkian, for which age in the Mount Lofty region Dr. Woolnough has proposed the term Barossian.

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[1] Australasian Inst. Mining Engineers, Vol. vi, No. 11, April 1910, by Messrs. R. J. Donaldson, C. W. Matters, R. T. Slee, J. C. Coldham, H. H. Walman, F. Voss Smith, and H. W. Davies.

There probably seems evidence in the Broken Hill region for a considerable divergence between the strike of the Archæan gneiss and that of the lower Cambrian rocks.

This Broken Hill evidence suggests that Mr. Howchin's conclusions as to the difference in strike of the Pre-Cambrian mountains of South Australia and the Cambrian may be reconciled with the apparent conformity of the two directions of strike in the Mount Lofty Ranges on the assumption that in the Pre-Cambrian complex there are at least two distinct groups, (1) an Archæan group chiefly formed of gneiss and other coarsely crystalline rocks, (2) an Algonkian (or Barossian) group, and that the folding of group (1) took place much earlier than that of group (2) and was divergent in direction from it. It may also be assumed that group (2) was heavily folded before the deposition of the lower Cambrian beds, so as to leave a considerable unconformity between it and the Cambrian system, but that the direction of folding was less divergent from that of the Cambrian than it was from that of the Archæan. Mr. Howchin concludes that there is strong evidence of the divergence of the Archæan folds of what he terms the Willouran and Babbage line, and those of the Cambrian in the region between Lake Torrens and Lake Eyre. The other alternative is to assume that both Algonkian and Archæan rocks have been folded on similar trend lines, which mostly diverge from the later trend lines of the Cambrian, though in places they coincide.

On the whole it may be said that in the neighbourhood of Spencer's Gulf, St. Vincent's Gulf and the Mount Lofty Ranges the divergence between the trend lines of the Barossian group and the Yorke Peninsula group on the one hand and those of the Cambrian on the other, do not appear to be very strongly marked. On the other hand there is strong evidence of (1) a spiral structure, and (2) of virgation.

The great spiral commences in Kangaroo Island where an east and west trend swings gradually into a N. by E. to N.N.E. direction through the Mount Lofty Ranges, with a fine series of overfolds directed towards the west. As the Barrier Ranges are approached, the trend lines virgate striking about E.N.E. (true) near Broken Hill. There the folds are overturned and the fault planes overthrust towards the S.S.E. Thus the 'sense' of the folding changes in the country which intervenes between the Mount Lofty Ranges and the Barrier Ranges. Mr. Howchin has shown that in the region which lies between the Barrier Ranges and Lake Torrens, the Flinders Ranges are not folded asymmetrically. Mr. Howchin[1] has shown that in the northern section of the Flinders region the trend lines, near Beltana, strike N.W. Mr. H. Basedow also states[2] (p. 81) that the Cambrian strata near the head (northern end) of Lake Torrens appear to strike from N. 25° W. round to W. This suggests that the old trend lines of the western part of the great virgation are swinging round to meet the trend lines of the Musgrave Ranges.

These ranges described by Gosse,[3] 1873, and by H. Y. L. Brown[4] and V. Streich[5] have also been examined and reported upon by Mr. H. Basedow,[2] who shows that these Pre-Cambrian ranges formed of gneiss, schist, granite, quartzite etc., have a dominant strike nearly E. and W. At Opparinna Spring he figures a strong overfold directed to the north. In the Kelly Hills the schists strike about

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[1] The Geography of South Australia, Whitcombe and Tombs, 1909, p. 90.

[2] Trans. and Proc. Roy. Soc. S.A., Vol. xxix, 1905, Geol. Rep. on the country traversed by the S.A. Gov. N.W. Prospecting Exp. 1903, pp. 57–103, pls. xiii – xx.

[3] Gosse, Central and Western Exploring Expedition. By authority, Adelaide, 1873.

[4] Rep. Journey from Warrina to Musgrave Ranges, p. 2, Adelaide. By authority, 1889.

[5] Sci. Results Elder Expl. Exp., Trans. and Proc. Roy. Soc. S.A., Vol. xvi, pp. 77 and 83.

N.N.E. (true), dipping at 40° to E. 21° S. (true). Mount Woodroffe, 5,200 feet high, in these ranges is perhaps the highest peak in South Australia. Beyond the western end of the Musgraves rise the Mann and Tomkinson Ranges. The Mann Ranges, also formed mostly of Pre-Cambrian rocks, exhibit planes of foliation and schistosity trending from between N.E. and S.W., to W. by N. and E. by S. The folding as shewn by Basedow (*op. cit.*, p. 62 and Pl. xix) is intense but not very asymmetrical. As far as can be judged from his figure there is a slight tendency for the folds to be forced over towards the north.

The Tomkinson Ranges, formed of Pre-Cambrian gneisses and schists, also have large intrusive dykes of olivine-gabbro and norite. The gabbro intrusions trend about E. and W. Diorite dykes follow the same trend. The planes of foliation of the gneisses trend north-easterly (Basedow, *op. cit.*, p. 75). In Ayers Range the gneissic folds have a general trend a little S. of W. and E. of N.

At Mount Conner there is a great unconformity between the Ordovician quartzites and the Pre-Cambrian crystalline group. The strike of the quartzite varies from W. up to W. 30° N. (magnetic). Mounts Kingston, Olga, and Ayers Rock are formed respectively of quartzite, conglomerate and metamorphic grit, considered by Tate and Watt to lie at the base of the Ordovician Series.[1] The Levi Ranges to the south of the MacDonnell Ranges are also formed of Ordovician rocks and folded according to the same authors on approximately E. and W. axes. The folds appear to be nearly symmetrical.

In the MacDonnell Ranges the same authors show that the Pre-Cambrian gneisses, schists, and quartzites of that region are very strongly folded, and that the trend in the central and eastern part of the MacDonnells is nearly E.

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[1] Rep. Horn Exp. Centr. Austr., General Geology, p. 59.

and W., whereas westwards the folds bend somewhat to W. of N. inclining eventually to W.N.W. As far as can be judged from the sections supplied by these authors, there is a slight overfolding from N. to S.

As regards newer structure lines it seems probable from the steepness of the southern escarpment of the MacDonnells and its narrow rocky cañons, such as those of Redbank Gorge, and the gorge of the Finke River, that there has been comparatively recent movement along an old E. and W. fault plane. The most important of these newer tectonic lines, as has been indicated by Mr. Howchin,[1] Prof. Gregory,[2] and Mr. W. N. Benson, B.Sc.,[3] are the series of important and comparatively recent zones of fractures which run more or less meridionally between the western scarps of the Mount Lofty Ranges and the high western plateau bounding Lake Torrens on the west. In this fractured and foundered area, termed by Professor Gregory the 'Rift Valley of Australia,' lie St. Vincent and Spencer Gulfs, Lake Torrens, Lake Eyre etc., the last mentioned at its centre being about sixty feet below sea level. This region appears to have been an area of subsidence from very early time. Even the lower Cambrian strata of Mount Lofty crept westwards in their effort to fill up this senkungsfeld; and in his latest paper Mr. Howchin has shown that even the Miocene strata to the south of Adelaide have been overfolded in the same direction.

The earthquake which visited the Adelaide region on September 19th, 1902, appears to have had its epicentre near Warooka towards the southern end of Yorke Peninsula. This proves that movement of the earth's crust along this important zone is still in progress. The accompanying section, Fig. 5, after Howchin, shows the probable structure of this senkungsfeld.

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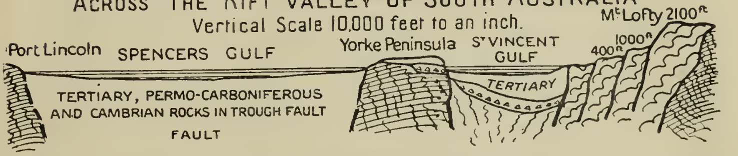
[1] Q.J.G.S., Vol. LXIV, p. 234 - 263, pls. xxvi - xxix. Geography of S. Australia, pp. 88, 89 and 100; and Trans. Roy. S. S.A., Vol. XXVIII, 1904, pp. 253 - 280, pls. xxxvii - xliv, and *ibid.* Vol. xxx, 106, pp. 227 - 262, pl. xi.

[2] Dead Heart of Australia.

[3] Trans. Roy, Soc. S.A., Vol. XXXIII, 1909, pp. 106-7, and *ibid.* 1910.

Fig 5. Sketch Section. (Suggested by works of Walter Howchin)
Across the Rift Valley of South Australia
Vertical Scale 10,000 feet to an inch.



We may now glance briefly at the trend lines of Northern Territory, as far as they are known. The Rev. J. E. Tenison-Woods[1] figures a highly folded series of crystalline rocks without giving the trends of the folds. Mr. H. Y. L. Brown[2] in several reports has, with his assistants, placed us in possession of our present information as to the dominant structure lines of that region. The following conclusions may be provisionally drawn from Mr. Brown's reports :—

(1) That the Pre-Cambrian schists and gneisses have been folded on lines whose directions vary from N. and S. to N.N.W. and S.S.E.

(2) That the lower Cambrian *Salterella* limestones and associated strata strike about N.W. and S.E. with lines of major faulting and zones of crushing trending in the same direction.

(3) That the Ordovician quartzites have been somewhat folded and strongly tilted, the chief direction of the tilt being towards a little W. of S. This tilting appears to be connected with the great tectonic lines which extend through New Guinea in an E. by S. and W. by N. direction.

(4) That the Permo-Carboniferous rocks have not been folded.

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[1] Report on the Geology and Mineralogy of Northern Territory. By authority, Adelaide, 1886.

[2] Northern Territory Exploration, 1895. Northern Territory of S.A., Report by H. Y. L. Brown. By authority Adelaide, 1905.

(5) That recently hot springs, such as those of the Douglas River have broken out along lines which trend between N. 35° W. and N.W.

We thus see in the Northern Territory evidence first of a N. by W. foliation of the Pre-Cambrian rocks, followed by a N.W. folding of the Cambrian strata, and this in turn succeeded by a general tilting of all the strata from Cretaceous downwards in a S. by W. direction, showing that this part of Australia has probably of late fallen under the control of the New Guinea lines of uplift. Much information on the subject of the tectonic lines of Northern Territory may be expected from Dr. W. G. Woolnough on his return from the Scientific Exploring Expedition in Northern Territory. We may now turn to the south eastern part of Australia, and review the tectonic lines of Tasmania, Victoria, and New South Wales.

Tasmania.—Mr. W. H. Twelvetrees, F.G.S.,[1] and Mr. T. Stephens, M.A.,[2] and Mr. R. M. Johnston, F.G.S.,[3] have devoted some attention to the dominant trend lines. Mr. Twelvetrees has shown that on the west coast of Tasmania the schists of Pre-Cambrian age strike about N. 20° W., at the Rocky River on the Waratah Corinna Road, and at Cox's Bight on the south coast Pre-Cambrian (Algonkian) biotite schists and quartzite strike N.N.W. to N.W. They dip at low angles to the S.W. Mr. Twelvetrees estimates a minimum thickness for these beds of about 13,000 feet. On the N.W. coast at Rocky Cape quartzites and quartz-schists (Algonkian) trend N. and S., or a little W. of N., and E. of S. At the Forth River micaceous schists, hornblendic schists with garnet and zoisite, and quartzites strike W. of N. with a westerly dip.

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[1] Rep. Austr. Assoc. for Adv. of Sci., Vol. XI, 1907, pp. 466 – 470, and *ibid.*, Vol. X, 1904, pp. 613 and 622 – 630.

[2] Proc. Linn. Soc. N. S. Wales, Vol. XXXIII, pt. iv, pp. 752 – 767, pls. xxiv – xxviii.

[3] Geology of Tasmania, by R. M. Johnston, F.G.S., etc. By authority, Hobart, 1888.

Infolded amongst these Algonkian rocks are strata of Cambrian, Ordovician and Silurian Age thrown into long folds approximately parallel to the older trend lines of the Pre-Cambrian rocks. These strongly marked N.N.W. and S.S.E. trend lines of the western side of Tasmania are crossed by a line of granite intrusion which may be termed the Waratah axis, as it runs through the Mount Bischoff Mine at Waratah; this trends about N.E. and S.W. On the east coast the long meridional line of granite intrusions extending from the Hippolyte Rocks on the S., through Maria and Schouten Islands, Freycinet's Peninsula, St. Patrick's Head, St. Helens and Cape Barren Island and Flinders Island, marks a strong N. and S. tectonic line.

In the V formed by these two dominant trend lines is enclosed the Permo-Carboniferous and Trias-Jura basin with their massive sills of quartz-dolerite or quartz-diabase. Mr. Twelvetrees has shown that the alkaline rocks of the Port Cygnet district have broken out along a line trending S. 40° W., and that the distribution of the melilite basalts of Tasmania indicate an eruptive line trending about E. and W., near Lake Sorrell, and about E. 10° N. near Hobart between Rokeby and One Tree Point. The geological faults of Tasmania have not yet been worked out. Mr. Montgomery[1] records minor faults with throws of about 200 feet at Beaconsfield to the north of Launceston.

Mr. E. C. Andrews[2] has enumerated some probable lines of heavy fault as indicated by physiographic evidence, as follows:—Ben Lomond, Western Tiers, Mounts Roland and Wellington, north-east coast and east coast. R. M. Johnston[3] has already figured, on direct stratigraphic evidence several important faults on the south side of Mount Wellington. The line of melilite basalt eruption already mentioned trending about E. 10° N., probably marks a fault along this line. The great scarp to the west of Cradle Mountain, 5,069 feet high, the highest point in Tasmania, probably marks a line of major faulting with a heavy throw to the west. At the same time the existence of the great resistent sills of quartz-dolerite thrust over the thick masses of soft sediment of the Trias-Jura and Permo-Carboniferous systems afford exceptionally favourable conditions in this part of the island for the formation of steep scarps by sapping, unassisted by faulting. A prolongation of this hypothetical line of faulting to the west of Cradle Mountain trends towards Hobson's Bay, in Victoria. Another possible dislocation line in Tasmania is the gap through which the railway line from Launceston to Hobart passes between Ross and Oatlands. There can be little doubt but that in Tasmania block-faulting has assisted sapping in producing the steep scarps of the 'tiers,' that inland plateau so much of which is over 4,000 feet above sea-level, with peaks such as Mount Wellington 4,400 feet, Mount Field (or Humboldt) 4,721 feet, Ironstone Mountain 4,736 feet, and Cradle Mountain 5,069 feet above sea-level.

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[1] Rep. Austr. Assoc. for Adv. of Sci., Hobart, Vol. IV, pp. 321 – 327.

[2] This Society's Journal, Vol. XLIV, 1910, p. 477.

[3] Geology of Tasmania, p. 163, see section opposite page.

Victoria.—A glance at *Plate 2* at once reveals the important fact that there are at least two widely divergent trend lines in Victoria. First there is the obvious trend of the Main Divide of Victoria from E. to W. Then there are the older lines having a nearly meridional trend, which mark the position of the Grampians, Howitt-Wellington mountains, Snowy River porphyries, and the deep valleys of the Kiewa and Mitta-Mitta Rivers, the former sunk some 4,000 feet below the summit of the Bogong Mountain. The geological map of Victoria shows that trending sympathetically with the Main Divide is the belt of Trias-Jura sandstone of the Wannon, Otway, and Gippsland areas. Between the last two regions lies the great valley of Victoria.[1]

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[1] The Geography of Victoria, by Prof. J. W. Gregory, D.Sc., F.R.S., p. 77

The central and western parts of this great valley are occupied by the basaltic lavas mapped on the sheets of the Victorian Geological Survey and recently described in detail by Professor E. W. Skeats.[1] This east to west sag of the trough of the "great valley" has led to the isolation of the Wannon Trias-Jura area from that of the Otway area, as the result of the inflow of the sea and deposition of marine sediments over this part of the basin in Tertiary time. The isolation has been further completed still later by the outflow of vast sheets of basaltic lava. Dr. T. S. Hall[2] has emphasised the isolation of the Otway region as the result of this subsidence along the great valley in his chapter "The Otways as an island." Mr. Reginald A. F. Murray[3] has given a brief account of the metamorphic rocks and crystalline schists of Victoria and their trend lines, as well as of those of the older Palæozoic rocks. He remarks that (*op. cit.*, p. 34) "The leading characteristics of the Lower Palæozoic rocks of Victoria are the normal N. Westly to N. N. Easterly strike, and the high rate of inclination of their bands caused by the crumpling or folding process to which they were subjected at a period not long subsequent to their deposition etc."

According to R. A. F. Murray, following A. R. C. Selwyn, Victoria as regards its older rocks and the lines of folding in older and newer Palæozoic time is a vast syncline extending from the crystalline schists of the Wannon and Glenelg Rivers on the west to the similar rocks of the Mitta-Mitta massif, or Benambra Highland on the east (*op. cit.*, pp. 37, –78). Professor Skeats figures as Archæan[4] (*op. cit.*, p. 231) the foundation rocks between the Hummocks and the

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[1] Rep. Aust. Assoc. Adv. of Sci., Brisbane, 1909, pp. 173 – 229, pls. i – iv.

[2] Victorian Hill and Dale, by T. S. Hall, M.A., D.Sc., Melbourne, T. C. Lothian, 1909, pp. 99 – 106.

[3] Victoria, Geology and Physical Geography. By authority, Melbourne 1887, pp. 36, 37.

[4] Rep. Austr. Assoc. Adv. of Sci. Brisbane, 1909, pl. i, p. 230.

Mount Stavely Range. This geosyncline between Benambra and the Glenelg River is warped across in a direction trending from about N. and S., or a little E. of N. and W. of S. by ancient axes or hinges of folding referred to by Professor Gregory as the line of the Colbinabbin Range.[1]

On the latest geological survey map of Victoria this area is coloured 'Heathcotian,' and referred with a query to the Cambrian. Sections across this supposed Cambrian axis have been published by Professor Gregory.[2] In section 7 (*op. cit.*) he shows a parallel axis to the Colbinabbin axis at Dookie. On the other hand Professor Skeats in his able and well illustrated paper marks with a query as basal Ordovician the diabase series of the Knowsley district N. of Heathcote. In any case all the Victorian geologists seem agreed that there is an old axial line of folding running approximately meridionally through Heathcote.

On either side of this Colbinabbin axis lie troughs of Ordovician rocks. These have been folded very strongly as shown by Mr. E. J. Dunn,[3] on lines about N. 25° W. (true) and E. of S. The folds near Bendigo (Sandhurst) are somewhat asymmetrical, the source of the thrust being to the E., so that the folds are overturned towards the W. So much have these Ordovician strata been compressed that for considerable distances they now occupy only one half of their original dimensions measured along E. and W. directions. Professor Gregory shows four troughs of Silurian rocks[4] infolded in the eastern Ordovician syncline between Keilor and Mount Wellington. A glance at the geological map of Victoria shows that the Snowy River porphyries of Lower Devonian (?) time were developed along a line of eruption approximately meridional, and the middle Devonian

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[1] The Geography of Victoria, p. 69, 70.
[2] Proc. Roy. Soc. Victoria, 1902, pl. xxv.
[3] Report on the Bendigo Goldfield. By authority, Melbourne, 1896.
[4] Proc. Roy. Soc. Vict., 1902, pl. xxv, section 5.

Buchan and Bindi limestones lie in troughs also approximately meridional. A very strongly marked trough is that in which lie the so called (on the geological map) Devonian, by others considered Carboniferous, rocks of the Mitchell, Avon, and Macallister River regions. These strata contain in places *Lepidodendron australe.* They mark a strong N.N.W. to S.S.E. trend line from Mount Wellington 5,363 feet to Mount Howitt and beyond. A good section across this area is given by Professor Skeats.[1] To the W. of the Macallister River a strong fault is marked having a trend presumably about N.N.W. and S.S.E. The upper Palæozoic rocks of the Mount Wellington and Macallister are shown dipping off an axis of intrusive serpentine.

With these late Devonian or early Carboniferous rocks folding in Victoria practically ceased. The Permo-Carboniferous glacial beds are mostly either nearly horizontal or but gently inclined. But near Bacchus Marsh, as shown by Messrs. C. C. Brittlebank and G. Sweet, F.G.S.,[2] they dip in a general southerly to south-easterly direction at angles of from 5° up to in places 45°. As the grooving on the rock surfaces and the carry of the erratics all points to the ice having moved from S. to N., and the whole surface of the country was probably overridden by ice from at least as far as Bacchus Marsh on the south to Beechworth on the north, the present Main Divide could not then have existed, but the gathering ground of the snowfields must have been situated near to, or south of, the present southern coast of Victoria. The strong southerly dip of the Permo-Carboniferous glacial beds near Bacchus Marsh suggests that the warping up of the Main Divide of Victoria took place chiefly in very late Palæozoic time, and was connected with the intrusions of the large batholiths of granite which lie mostly a little north of the present Main Divide. At the same time the distribution of these granites between the Strathbogie Ranges and Cape Liptrap suggests that meridional trend directions were still operative though on the whole dominated by the E. and W. trends. That the warping was continued into Mesozoic time is proved by the tilting into broad basins of the Wannon, Otway, and Gippsland Trias-Jura strata with their associated coal seams. These E. and W. lines, which may be termed Bassian lines (after Bass Strait), continued to develop during Tertiary and Post Tertiary time. Eocene marine strata along the axis of the Great Valley of Victoria have been raised fully 800 feet above sea level. As already stated, the line of major fault, which has given rise to the steep escarpment W. of Bacchus Marsh, appears to have originated in Tertiary time and developed along the Bassian lines as did the E. and W. fault near Sorrento on the southern side of Hobson's Bay (Port Phillip). Nevertheless while the E. and W. warp lines dominated earth movement in Victoria in Mesozoic and Cainozoic times, evidence is not wanting to show that the forces which had produced the old N. and S. trend lines were not entirely in abeyance.

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[1] Rep. Austr. Assoc. for Adv. of Sci., Brisbane, 1909, pl. ii, fig. 2, p. 233.

[2] Rep. Austr. Assoc. for Adv. of Sci., Adelaide, 1893.

Mr. Stanley Hunter[1] has shown that the floors of the Tertiary rivers have been much warped, so that for some distances the drainage direction is reversed, so that streams once flowing south like those of Ballarat have now a rising instead of a falling gradient down stream, and moreover they show evidence that their eastern bends have been tilted up showing that the ranges to the east have been uplifted subsequent to the formation of the lead. He also records the fact that comparatively recent fault lines are occasionally met with in the alluvial workings for gold with displacements of about 30 feet, (*op. cit.*, p. 5). This evidence agrees with that mentioned to me by Mr. — Mahony, B.Sc., of the Geological Survey of Victoria that the recent dune rock near Sorrento is heavily faulted to the east of Sorrento in a N. and S. direction with a downthrow to the W. This fault trends northwards through the gap in the range through which the Melbourne to Sydney railway line passes to the south of Seymour.

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[1] Mem. Geol. Surv. Victoria, No. 7, Deep Leads. By authority, Melbourne, 1909, p. 4.

The homoseismic lines for the earthquakes of May 10, 1897, and May 27, 1900, suggest that the older meridional lines and the newer Bassian lines are still being followed by earthquake cracks.[1] The nature of the folding to which Victoria has been subjected is shown on fig. 6 *a* and *b*, and the trend lines are shown on *Plate 2*.

SECTIONS ACROSS VICTORIA

Fig. 6 (a).

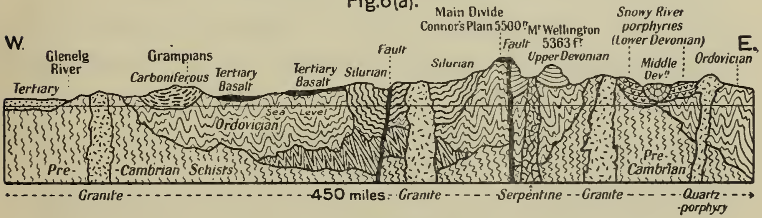
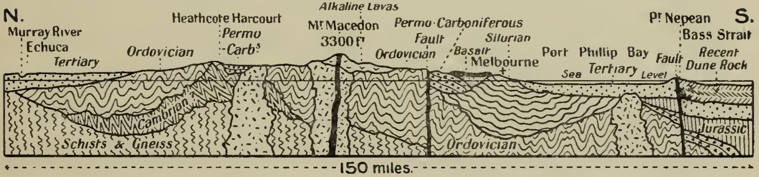


Fig. 6 (b).



New South Wales.—The outlines of the chief tectonic features of this State were traced with a masterly hand by the Rev. W. B. Clarke, F.R.S.[2] The late Government Geologist, C. S. Wilkinson, constructed a valuable map of the Hartley Bowenfels District which shows the folds of the Devonian rocks of that neighbourhood, and did much to elaborate the geological map outlined by Mr. Clarke. This has been added to under the direction of Mr. Wilkinson's successor Mr. E. F. Pittman, Assoc. R. S. M., by himself and the officers of his Geological Survey, notably Mr. J. E. Carne, F.G.S., and Mr. E. C. Andrews, B.A., while the maps of the Southern Coalfield by Messrs. J. B. Jaquet, Assoc.R.S.M., and L. F. Harper, F.G.S., and that of the Hunter River Coalfield by Messrs. G. A. Stonier, W. S. Dun, O. Tricket and myself have added information on tectonic movements of the crust since Permo-Carboniferous time. These observations have been supplemented by the valuable work of Dr. H. I. Jensen, D.Sc., on the alkaline rocks of the Canobolas, Warrumbungle and Nandewar Ranges.[1] Messrs. C. A. Süssmilch, E. C. Andrews, and C. Hedley, have lately contributed useful and suggestive papers on the physiography of New South Wales, references to which have already been given at the commencement of this address. Dr. W. G. Woolnough, D.Sc.,[2] and Mr. F. G. Taylor, B.A., B.E., B.Sc.,[3] have also added to our knowledge of the physiography of this State. The physiographic method of study of earth tectonics is obviously of special value in New South Wales, where along the whole of its Main Divide and coastal area marine strata later than the Permo-Carboniferous are unknown. In New South Wales there are two chief lines of trend, the older trends, (the direction of which is well shown by the orientation of the trough axis of our main coal basin) running N.N.W. and S.S.E., inclining to a more meridional direction southwards towards Kosciusko, and newer trends running parallel or sub-parallel to the present Pacific Coast, and that trends N. by E. to S. by W.

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[1] Geography of Victoria, by Professor Gregory, p. 175.

[2] Southern Goldfields of New South Wales, and remarks on the Sedimentary Formations of New South Wales. Fourth edition 1878.

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[1] Proc. Linn. Soc. N. S. Wales, 1909, Vol. xxxiv, pt. 1, by C. A. Süssmilch, F.G.S., and H. I. Jensen, D.Sc., pp. 157 – 194; *ibid.* 1907, xxxii, pt. 3, by H. I. Jensen, pp. 557 – 626, 842 etc. Also for general reference to distribution and trend lines of these alkaline rocks of East Australia together with references, see *ibid.* 1908, Vol. xxxiii, pt. 3, pp. 491 – 588, and particularly Fig. 10 on p. 585.

[2] *Ibid.*, 1906, Vol. xxxi, pp. 546 – 554.

[3] Commonwealth Bureau of Meteorology. Physiography of Proposed Federal Territory at Canberra, Bulletin No. 6, 1910, and *ibid.* Bull. No. 8.

The latter trends are well shown by Mr. Andrews.[1] The tectonic feature which is most conspicuous in the geology of New South Wales is the great syncline, in which lies the Permo-Carboniferous coal-basin, the main axis of which extends from Sydney to Gunnedah and Narrabri. This divides at once the Bathurst-Monaro highlands, or tableland, from the New England tableland. In the former tableland the older trend lines are well shown by the direction of outcrop of the chief beds of limestone, of Silurian age, which there run N. and S. Towards the northern edge of this plateau these fold lines swing more to the W. of N., the chief synclinal troughs in the upper Devonian series lying along N.N.W. to N. 30° W. directions. There is a strongly marked unconformity, recorded and figured by Dr. W. G. Woolnough in the gorge of the Shoalhaven near Tallong, between the Ordovician slates and the Silurian limestones. The folding of the Ordovician rocks has also been much more intense than those of the Silurian. In the Yass district the general trend of the folds in the Silurian and Lower Devonian rocks is about N. 15° W. and S. 15° E., as shown by Mr. Harper[3] and myself.[4] The prevailing dip is to about W. 15° S. At Yalwal Mr. Andrews has shown that the Upper Devonian rocks, lying in a long and narrow basin, trend nearly due N. 30° E. (true). If we examine the direction of strike of elongated masses of intrusive granite from Delegate on the S. to Bathurst on the N., we find that there is a slight tendency to virgation, the great mass of granite extending from Bombala to Braidwood runs N. 15° E. and S. 15° W., but the mass extending from the Snowy near Forest Hill to Adelong trends about N. 8° W.

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[1] This Society's Journal, Vol. XLIV, p. 347.

[2] Proc. Linn. Soc. N.S. Wales, 1909, Vol. XXXIV, pp. 783 – 5.

[3] Geol. Surv. N.S. Wales, 1909, Vol. IX, pt. 1, pp. 1 – 53.

[4] Ann. Rep. Depart. Mines, 1882, p. 148, with maps and sections.

In the Forbes-Parkes Goldfield[1] Mr. Andrews shows the trend of the Silurian folds to be N.N.E. with suggested overthrusts to the E.S.E., an approximation to the Broken Hill trends in pressure directions. In the Cobar region Mr. Andrews finds the strike of the Silurian limestones and conglomerates and Devonian quartzites is generally about N.N.W., with several major faults apparently overthrusts striking in the same direction with the overthrusting being towards the west. Traced in the direction of Girilambone, the strike changes to N. and even N.E., the rocks there being schists and quartzites, possibly, as Mr. Andrews thinks at present, Pre-Cambrian. Possibly these latter rocks represent an offshoot from the Pre-Cambrian series of Broken Hill which have, as already stated, prevalent north-easterly trends. Mr. C. S. Wilkinson[2] shows that the strike of the Devonian beds, W. of the Blue Mountains is N.N.W. and S.S.E., and Mr. J. E. Carne's work confirms this. At the same time the strike of the Jenolan Cave *Pentamerus* limestone, in the Silurian rocks, is nearly N. and S. with a westerly dip. Mr. C. A. Süssmilch[3] and Dr. H. I. Jensen[4] have referred to the folded rocks of Silurian and Devonian age in the Canobolas region, and the former determines the strike of these folds as about N. 30° W. (true).

Near Ponto to the west of Wellington, a very strongly developed and intensely folded trough in the Devonian and Silurian rocks has lately come under my notice. If the strata are not repeated by isoclinal folding and faulting, nearly 10,000 feet of red sandstones and shales are there developed lying in a trough, the axis of which trends nearly N. and S. from a little W. of Wellington towards Molong. Mr. Süssmilch[1] has already called attention to the strong disturbances of the nature of recent faulting, determined on physiographic evidence, extending from Jindabyne and Cooma, in the former case north-easterly, in the latter northerly. The Cooma-Colinton line of fractures is parallel to the upper course of the Murrumbidgee, that is about N. 5° W. Mr. T. G. Taylor has further examined the zone of faults between Lake George and the Murrumbidgee River near the site of the Federal Capital at Canberra. In his latest work he refers to this Snowy-Murrumbidgee line of disturbances as a rift valley running northwards to the volcanic region of the Canobolas, and thence by way of Wellington to the volcanic zone of the Warrumbungle volcanic necks. These faults, described by Süssmilch and Taylor, are of course recent faults for the most part belonging to the present cycle of erosion, but they appear to be established along old lines of intense folding and major faulting. It is much to be desired that a reliable cross section of this beautiful tectonic region between Bathurst and Parkes be obtained by actual survey. An important fact to be noted in the Bathurst-Monaro tableland lying to the south of the great central coal-basin, is that along its north-eastern margin is an extensive belt of Devonian rocks which strike nearly conformably with the axis of the main trough of the great coalfield. One would expect to find the overfolds of the Devonian rocks directed here towards the main axis of subsidence ; on the whole, though the dips are often reversed in the neighbourhood of axes of intrusive masses of granite, the marginal

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[1] Depart. of Mines, Geol. Surv., Mineral Resources No. 13, by authority 1910.

[2] Geological map of the districts of Hartley, Bowenfels, Wallerawang, and Rydal.

[3] This Society's Journal, Vol. XL, p. 130, 1906.

[4] Proc. Linn. Soc. N. S. Wales, Vol. XXXIV, pt. 1, 1909, pp. 158 - 194.

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[1] This Society's Journal, Vol. XLIII, pp. 331 – 354, pls. ix – xiii.

Devonian rocks show a tilt towards the E.N.E., that is in the direction of the main basin.

If now we examine the important unit of the New England tableland, the following tectonic lines are obvious :—The long belt of serpentine recently described in detail to this Society by Mr. W. N. Benson. This extends for fully 150 miles from Nundle to Bingara, striking in a general N.N.W. and S.S.E. direction. The Carboniferous and Devonian rocks have been folded and powerfully fractured along the same line, the pressure coming from E.N.E. from about E. 17° N. (true). Further north in the Emmaville district of New England, the Permo-Carboniferous, and perhaps Carboniferous claystones, are folded on lines trending about N. 30° W. and S. 30° E., with evidence of the pressure having come from E. 30° N. The trend of the Permo-Carboniferous limestones near Kempsey is about N. 35° W. (true). On the other hand the great intrusive masses of granite which occupy so large a part of the country between Tamworth and Wallangarra on the Queensland border strike about N. 22° E. (true). This direction is almost exactly parallel with the coast line, and shows that in New South Wales as in Victoria, the axes along which the granites were intruded belong to the newer trend lines which determined the position and orientation of the present coast line.

Mr. E. C. Andrews has shown that in the New England district the granites have strongly intruded the Permo-Carboniferous rocks, whereas in the Lithgow district of the western coal-field rolled pebbles of the Hartley granite are very frequent in the basal upper marine Permo-Carboniferous rocks of that area. The long axis of the Clarence Basin is exactly meridional (true). Another important tectonic line is the belt of alkaline lavas which form such conspicuous elevated and isolated groups on the relief model, *Plate 1*, extending from the extinct volcanoes of the Canobolas through those of the Warrumbungle mountains to those of the Nandewar Ranges.

The trend of this great alkaline belt and its prolongation in Queensland through the Macpherson Range, Cunningham's Gap, and the Glasshouse Mountains on to Yeppoon, near Rockhampton, and thence to Clermont, has been well shown by Dr. H. I. Jensen.[1] The trend of the Canobolas to Nandewar line is about N. (true) from the Canobolas to the Warrumbungles, and N. 35° E. from the Warrumbungles to the Nandewars. The line of trachytic eruptions is prolonged in a S.S.W. direction from the Warrumbungle mountains to the Gibraltar Rock near Dubbo.

As regards now the chief tectonic lines in the great central coal-field, there are two well marked directions, the first set running more or less parallel to the general axis of the trough in which the basin lies, (in the Lower Hunter district this is shown by the Greta etc. faults, running from between E. 30° S. and E. 10° S. to W. 30° N. and W. 10° N., in the southern coal-field they trend in a general E.S.E. and W.N.W. direction). In this first set of faults the throw in each case is in towards the centre of the basin. The other set of faults runs more or less parallel with the coast line. A well marked trend belonging to this set, is the flat asymmetrical anticline forming the eastern escarpment of the Blue Mountains. This was referred to by me in previous papers to this Society.[2] The general trend of this fold is N. 15° W. (true). It is to be noted that this structure makes an angle of nearly 35° with the fold of the continental shelf. It cannot therefore be correctly described as a parallel structure. The continental shelf has been ably described in detail by Hedley.[3]

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[1] Proc. Linn. Soc. N.S. Wales, 1908, No. 131, pt. 3.

[2] This Society's Journal, Vol. xxx, 1896, pp. 33 – 41; Vol. xxxvi, 1902, pp. 399 – 370, pls. xvi, xvii.

[3] Presidential Address, Proc. Linn. Soc., 1909, and *ibid.* 1910.

The heavy fracture known as the Elderslee Fault, west of Branxton, has a throw to the west of perhaps 5,000 feet.[1] Its trend is at its southern end N. and S. (true), and north of the Hunter River N. 9° W. (true). The strata in this part of the coal basin are thrown into a series of broad synclines and anticlines whose axes trend a little W. of N. and E. of S. Their steeper sides face inland, as though the pressure came from the direction of the Pacific Coast and pushed the strata in towards the subsidence region of the great coal basin. Thus there is evidence of a crustal creep towards the coal basin, but along hinges of folding which have an orientation intermediate between that of the long axis of the coal basin and the trend of the coast line. It is the evidence of the new pressure lines, (which eventually merged into the epeirogenic uplift which eventually formed our coast line and Main Divide) beginning to assert themselves. The principal lines of faulting in late Tertiary and Post Tertiary time, mapped chiefly on physiographic evidence have been ably described by Messrs. E. C. Andrews,[2] C. A. Süssmilch,[3] and T. Griffith Taylor.[4] These faults in the Monaro tableland are not parallel to the coast line but diverge some 25° to 30° from it. The trend of these fractures is mostly between N. 5° W. and N. 10° W. (true). But in the case of the fault scarp to the east of the Gourock Range Mr. Andrews shows this as being parallel to the coast. In the New England tableland the fractures on either side of the axis of granitic upheaval, as far as they have been traced, trend somewhat W. of N. following near to the direction of folds in the older rocks. The newest scarps of all may be more nearly parallel with the coast, but this point yet awaits investigation. Mr. Andrews has well shown that in this latest epeirogenic uplift the maximum effect was produced at the mountain knot of the S.E. corner of Australia where the meridional direction of flexing met the cross flexing of the Bassian lines (*op. cit.*, pp. 431-2).

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[1] Geological Map of the Hunter River Coal-field, Geol. Survey, Dept. of Mines, Sydney.

[2] This Society's Journal, Vol. XLIV, pp. 420 – 480.

[3] *Ibid.*, Vol. XLIII, pp. 331 – 354, pls. ix – xii.

[4] Proc. Linn. Soc. N.S. Wales, 1907, Vol. XXXII, p. 327; also Commonwealth Bureau of Meteorology, Bulletin No. 6 ,1910, "The Physiography of the Proposed Federal Territory at Canberra,"

The recent epeirogenic uplift which has produced the present Main Divide and coast line and accentuated the continental shelf has the form of a gentle wave with its steeper side directed to the Pacific, a fact emphasized by Hedley. Hence for some time past the tendency has been for the Divide to be forced inland, that is westwards, through the steeper eastern rivers capturing the upper portions of the watersheds of their more sluggish western neighbours. Quite recently a downward joggle has taken place for a considerable distance along the coast, especially marked along the seaward edge of the great coal basin. This depression has amounted to about 200 feet. A very recent negative movement of the strand-line to the extent of about 15 feet is so general around Australia as to suggest that it may have been due to a eustatic negative movement of the whole ocean surface in the Southern Hemisphere, due to some such cause as a locking up of sea water in the snowfields and glaciers of the Antarctic following on after extreme deglaciation during an interglacial epoch.

We thus see in New South Wales a marked example of development of two sets of tectonic lines, the older an orogenic set of strong folds with numerous normal and some overthrust faults in each case directed inwards towards that master warp the great central coal-field, the newer set, of an epeirogenic nature, is a gentle flex, the hinge parallel to the continental shelf, coast line, and present Main Divide; but the normal faults with downthrows away from the main axis of upheaval in many cases show by their orientation a compromise in direction between the older orogenic folds and the newer line of epeirogenic uplift.

SECTIONS ACROSS NEW SOUTH WALES.

Fig 7(a).

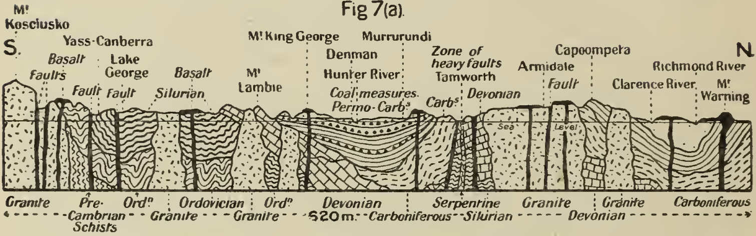
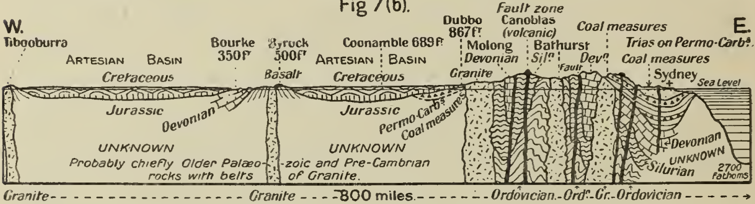


Fig 7(b).



Queensland.—We may now glance at the salient points in the tectonic geology of Queensland. Reference to *Plates 1* and *2* of this address reveal the following dominant features:—

(1) Ranges mostly of Palæozoic rocks forming the highlands of the Main Divide, an ancient peneplain trending about N. 33° W.

(2) A great basin of newer and softer rocks, the Cretaceous basin, with at its S.E. extremity an older basin of soft rocks, the Trias-Jura Basin. This forms a Y, the lower stroke of which is the Clarence Basin of New South Wales.

(3) A plateau of older rocks in the neighbourhood of Cloncurry, rising to the Barclay Tableland near Camooweal.

(4) The Great Barrier Reef may be added as a fourth unit which has shared in the tectonic development of Queensland.

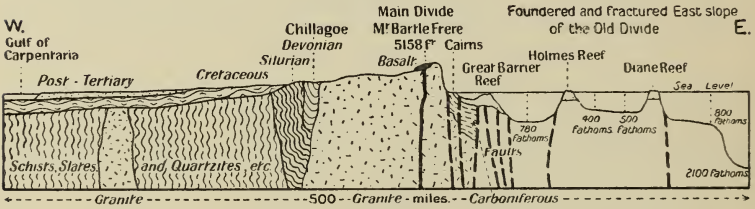
As regards topographical relief one of the most conspicuous features in Queensland is that of the steep-to Ranges along the northern coast. These ranges form a very steep-to coast from opposite Hinchinbrook Island through the Bellenden-Ker Ranges, 5,438 feet high, (the highest ranges in Queensland) to the north of Cairns. The Bellenden-Ker are situated only about ten miles inland from the coast, and Hinchinbrook Island, formed of granites, schists, slates, etc., is 3,650 feet high. This steep-to coast has remarkably short rivers draining eastwards, as the Main Divide is here so close to the ocean. Western rivers, like the Gilbert and Mitchell, on the other hand, flow down long gentle slopes to the Gulf of Carpentaria. This steep-to coast is situated, for the most part, all along the area facing the Great Barrier Reef.

There can be no doubt that a very important tectonic feature is indicated by this remarkable type of coast. Mount Bartle Frere in the Bellenden-Ker Range is 5,438 feet above sea-level; is formed of granite and is yet only fourteen miles inland from the coast. Peter Bott, also of granite, and 3,311 feet high, is only five miles back from the coast. "Rough Round Hill," about one hundred miles north of Princess Charlotte Bay, only three miles inland is 1,543 feet high, and also formed of granite. In fact the Main Divide near the Bellenden-Ker Range just north of Cairns is only eight miles distant from the Pacific on the east, whereas the nearest ocean, the Gulf of Carpentaria on the west is 275 miles distant. This extraordinary position of the Main Divide taken in conjunction with the evidence of waterfalls like the Barron Falls, 800 feet high, and the numerous high granite and slate islands is almost certainly due to comparatively recent crust foundering on a grand scale along the region of the Great Barrier Reef, whereby almost the whole of the eastern side of the old

Divide has been let down below sea-level. Thus only a few miles of the heads of the eastern rivers have been preserved. As the result of this extreme betrunking they have become greatly overhung above the foundered area. Hence the steep-to coast and high waterfalls. The theoretical structure of this part of Queensland, near Cairns, is shown on Fig. 8.

SECTIONS ACROSS QUEENSLAND

Fig. 8.



As regards unit (1) the Main Divide, an examination of the geological map of Queensland shows that it is formed largely of granites, and so-called Gympie rocks[1] which may be more appropriately termed the Star Series. These differ from the true Permo-Carboniferous rocks in containing *Lepidodendron* and *Aneimites*, allied to *Rhacopteris*, as contrasted with the *Glossopteris-Gangamopteris* Flora of the Permo-Carboniferous System. West of Townsville the Middle Devonian rocks of the Burdekin System form part of the Divide, and near Chillagoe Mr. R. Etheridge[2] has recorded *Halysites* from Silurian rocks. Probably older rocks of slates, schists, quartzites, etc., extend from Springsure to near Townsville, and from west of Canoona in the Rockhampton District in the direction of Bowen.

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[1] As the Gympie Rocks in the type district now prove to be Permo-Carboniferous, in the meaning of that term as used by New South Wales geologists, it is no longer an appropriate term for the *Lepidodendron* Beds of the older (Carboniferous or possibly Upper Devonian) formations. The term Star Series will be used in this address for the latter.

[2] Geol. Sur. Queensland, Publication No. 190. Records No. 1, VIII, pp. 30–32.

Enclosed between these two old belts of Silurian or Pre-Silurian rock is the northern end of the great coal-basin of Queensland. This extends to near the head of the Dawson River. Its main axis strikes about N. 27° W. (true). The long axes of the intrusive masses of granite follow approximately parallel directions, as do the folds in the Gympie rocks.

At its north end the Bowen Coal Basin is abruptly rounded off by an immense bar of granite trending nearly due E. and W. (true). At Peak Downs the folds have a general north-easterly to south-westerly trend. At the Cape and Charters Towers the trend of the folding in rocks of Pre-Burdekin (Pre-Devonian) age is about W.N.W. and E.S.E.. W. H. Rands[1] estimates that the schists and quartzites of the Cape River Gold Field may have a thickness, without allowing for possible repetition of beds, of from five and a half to six miles, they dip at 30 – 35° towards S.S.W. At Chillagoe the folds strike about E.S.E.. In the Middle Devonian rocks of the Burdekin Basin the folds trend about N. 40° E. and S. 40° W. Dr. R. L. Jack, in 1894, wrote to me "There is no evidence as to when this folding took place in Queensland as the Devonian is not seen anywhere in contact with newer rocks, and so we cannot tell whether they have been folded together or not. The hiatus, however, between middle Devonian and our next series (Gympie) itself implies an upheaval and in all probability a folding prior to Gympie," (*i.e.* Carboniferous times.—T.W.E.D.)

It is worthy of note that these Burdekin folds trend at right angles to the adjacent coast line. In the Gilbert Gold-field, still further north, there are two well marked sets of folds, trending respectively E.S.E. to W.N.W., and

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[1] On the Cape River Gold Field. By authority Brisbane, 1868.

W.S.W. to E.N.E. The latter are in sympathy with the Burdekin and Kimberley lines, and the former with those of the Cape Gold-field and the New Caledonia to New Guinea lines and the Charters Towers granite axis.

Dr. R. L. Jack wrote me in 1894, "The folding of the Gympie formation [Gympie here used in the sense of *Pre-Star* (that is Pre-Upper or Middle Carboniferous) and Post Burdekin (Post-Middle Devonian)—T.W.E.D.] must have been the chief factor in the evolution of the eastern coast range. That it took place before the deposition of the Star formation I have little doubt in my mind, as the latter though nowhere observed in contact with the Gympie, is comparatively undisturbed." Dr. Jack would probably in view of later palæontological determinations which show that much of the Gympie beds are really newer than the Star beds, and that the Gympie has certainly in places been folded fairly strongly, see his way to modify this statement, so that one might conclude that one of the chief factors in the evolution of the Main Divide has been the folding of the Carboniferous and Permo-Carboniferous rocks along lines mostly coincident with the long axes of the granite batholiths. Trend lines are also indicated in the Main Divide unit by the general distribution of the main basalt flows and volcanic foci. Notably to the east of Clermont these foci are grouped along N. 40° W. and S. 30° E. lines.

Dr. H. I. Jensen[1] has indicated the trend lines of the foci and general zone of the alkaline lavas in the Mount Flinders and Fassifern districts and the east Moreton and Wide Bay districts. In the former district the zone trends about N.E. and S.W. (true), but the local groups of volcanic foci appear to trend about N. 15° W. to S. 15° E. (true). In the latter district the trend is N. and S. (true). Trend lines are also shown by the belt of serpentine to the west of Gympie (about N. 10° W., true) and the immense mass of serpentine to the north of Rockhampton. The latter trends N.W. and S.E. true, and is evidently situated on a zone of heavy fractures. These extend all the way from Gladstone to Herbert Creek at Broadsound. The trachyte volcanic centres of Yeppoon and Berserker Ranges are close to these major lines of fracture. They are doubtless part of the group of great fractures along which the former eastern side of the Divide has been stepped down below sea-level. There is both physiographic and stratigraphical evidence for this fault at Curtis Island.

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[1] Proc. Linn. Soc. N. S. Wales, 1903, pt. 4, ap. 842 – 875, pls. xlvi – l; *ibid.*, 1906, pt. 1, pp. 73 – 173, pls. v, v *bis* – xvi; *ibid.*, 1908, Vol. xxxiii, pt. 3, pp. 491 – 588, especially p. 585; *ibid*, 1909, Vol. xxxiv, pt. 1, pp. 67 – 104, pls. i – vi.

Mr. Lionel V. Ball, B.E.,[1] shows on map 11 of his instructive report, that there is a basin of Burrum Beds (Trias, or Trias-Jura) thrown against Devonian rocks. The Boyne River follows this line of fault, which, presumably throws to E. 40° N. The channel between Curtis Island and the mainland is on a continuation of this fracture. Beyond Keppel Bay it seems to divide, an eastern branch going to Shoalwater Bay and the Northumberland Islands, the western to the estuary of Herbert Creek, at Broadsound. Another profound fracture, observed by me in 1891, bounds the Styx River Coal-field on the East. I estimate that it has a throw of fully 3,000 feet. It is probably prolonged to where on the chart of the Barrier Reef, north of Broadsound, the note occurs "it is unsafe to pass to the eastward of this line." If so, this fault has a length of fully 250 miles. This trends in a S. by E. direction, striking for the Dawson River to the east of Duaringa. Several important faults have been recorded by Mr. B. Dunstan in this region.

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[1] Geol. Surv. Queensland, Publication No. 194, "Certain iron ore, manganese ore, and limestone deposits in the Central and Southern Districts of Queensland." Brisbane, by authority, 1904.

The trend of the "Gympie" and Permo-Carboniferous-*Glossopteris* Beds is, according to Dunstan, about W. 40° N. with a dip to S. 40° W.[1] The Cumberland Islands and Whitsunday Island are almost certainly horsts amongst a network of faults. The trachytic volcanoes described by Mr. A. Gibb Maitland[2] to the W. and N.W. of Mackay, such as Mount Mandurana, Mount Jukes, etc., mark a continuation of the disturbance lines in this zone, upon which are seated the above extinct trachyte volcanoes. A few other important fault lines may be mentioned. Dr. Jensen[3] figures a probable line of fault running from near Mount Flinders in a N. by W. direction to the west of Ipswich. Several faults are figured on the geological survey maps of the Ipswich Coal-field, these have a general trend N.W. to N.N.W., with a throw to N.E. Dr. Jensen[4] has figured a fault north of Brisbane, striking W. 40° N. to S. 40° E., and throwing probably at least 1,000 feet to N. 40° E. To the south-west of this fault lie the phyllites, hornblende schists, glaucophane schists, anthophyllite schists, cyanite-rutile granulites, etc. of the Mount Mee and D'Aquilar Range area. This appears to have been the core of the old Main Divide. In the Gympie Gold-field are a large number of faults which have been mapped by Mr. W. H. Rands, F.G.S.,[5] and Mr. B. Dunstan.[6] The "Smithfield Crosscourse" runs E. 10° N. (true) with a N. 10° W. downthrow of 530 feet. The normal strike of the Gympie strata is in a general N. by W. and S. by E. direction. The Inglewood Fault strikes near E.

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[1] Geol. Surv., Queensland, Bulletin No. 11. Report on the Geological Features of the country between Warren and Mount Lion in the Rockhampton District. Brisbane, by authority, 1900.

[2] Geol. Surv., Queensland. Geological Features and Mineral Resources of the Mackay District. By authority, Brisbane, 1889.

[3] Proc. Linn. Soc. N. S. Wales, 1909, Vol. xxxiv, pt. 1, pp. 67 – 104, and specially pl. i.

[4] Proc. Linn. Soc. N. S. Wales, 1906, Pt. 1, p. 103, and see fig. 3, p. 76.

[5] On the Gympie Goldfield. By authority, Brisbane, 1889.

[6] Report of Geol. Surv. in course of publication.

30° S., with a throw to N. 30° E., and the Laing's Fault strikes N.N.W. to N.W., with a throw towards N.E.

An important tectonic structure to the south of Princess Charlotte Bay, to the north-west of Cooktown is the senkungsfeld of the Little River Coal-field. This strongly marked trough is well figured by Dr. R. L. Jack.[1] The indent in the coast at Princess Charlotte Bay is probably of tectonic origin. A significant fact in the structure of the unit of the Main Divide of Queensland is the newness of the folding and faulting. In the southern part of New South Wales the Permo-Carboniferous strata are simply thrown into broad undulations. In the New England district they are strongly folded and altered by granites. At Gympie they are much disturbed and considerably altered in places. About five miles north-west of Gympie specimens of *Protoretepora* occur completely replaced by stibnite.[2]

The Trias-Jura Coal-measures of the Styx River at Broadsound are thrown into broad folds, and at Maryborough the Maryborough Beds, classed by R. Etheridge as of Upper Cretaceous age, dip at angles varying from 7 – 12° up to 30 – 45° on the Isis River, as recorded by W. H. Rands.[3] The general dip is north-easterly. Nowhere else in Australia, as far as I am aware are strata as new as Upper Cretaceous so much disturbed, as in the above district. The comparatively recent character of the volcanic eruptions in the Cairns district is proved by the crater lake surrounded by scoria described by Mr. Meston, Lake Eacham.[4] The great submarine volcanoes perhaps the largest, which have as yet been discovered in the Australian region, lying between 104 – 128 miles east of Brisbane are probably of recent origin. These have been referred to by C. Hedley,[1] and are shown on the accompanying fig. 9.

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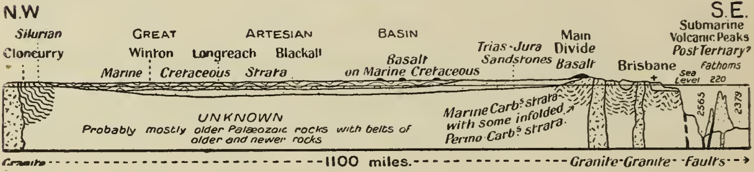
[1] Report on the Little River Coalfield. By authority, Brisbane, 1882.

[2] Geology and Palæontology of Queensland and New Guinea, Jack and Etheridge. By authority, Brisbane, 1892, p. 83.

[3] Report on the Burrum Coal-field. By authority, Brisbane 1896.

[4] Geol. and Pal. etc. *supra*, p. 587.

Fig. 9



The highest of these mountains is about 14,000 feet in height, at Lat. 28° 42′ 2″, Long. 155° 37′ E. As far as can be judged from the soundings these submarine volcanoes have a general N. by W. to N.W. trend.

As regards unit (2) the Queensland portion of the Great Artesian basin, little need be said from a tectonic point of view, except that the basin represents an area which was partly covered by great warp lakes in Trias-Jura time, and wholly covered by sea in Cretaceous time. The basin was deepest near its centre just over the border of South Australia from Queensland. There the sediments of Cretaceous and perhaps Trias-Jura age in part are a mile in thickness. Between Cloncurry and Hughenden (J. B. Henderson)[2] a large sill of Palæozoic rocks, rising to within about 1,000 feet of the surface of the ground, forms a partial subterraneous barrier to the Artesian basin. It trends in an E. to W, direction. The north-westward flowing tributaries of the Darling, such as the Bogan, Macquarie, Castlereagh, Namoi, Gwyder in New South Wales formerly entered the south-eastern shore line of this Cretaceous sea by separate mouths. Subsequently, in Eocene time, a broad epeirogenic uplift supervened raising the whole basin, especially in the direction of New Guinea, the southern shore line of Australia undergoing submergence in Victoria, the southern part of South Australia, and the south-western part of New South Wales. This tilting from N. to S. in time started the Darling, the Bogan, and Macquarie rivers etc., now forming what Mr. T. G. Taylor[1] has called 'boathook bends' with the main stream.

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[1] Proc. Linn. Soc. N.S. Wales, Vol. xxxvi, pt. 1, pp. 32, 33.

[2] Hydraulic Engineer's Report. By authority, Brisbane.

(3) In reference to the third unit, that of the Cloncurry region ascending to the Barclay Tableland beyond Camooweal, information as to its tectonic lines is at present very meagre. As regards recent uplift, as shown by Mr. E. C. Andrews,[2] the Main Divide of Queensland has been warped up synchronously with the Main Divide of New South Wales. Dr. Jack has pointed out in an able lecture, quoted by Mr. Hedley, that the Main Divide of Queensland was formerly close to Brisbane, but now has been pushed westwards by the rivers draining the eastern, the steeper, slope of the warp, so that it is now, at the latitude of Brisbane, some 50 miles west of its former position, owing to the eastward flowing rivers having cut back their channels through the hard argillites and granites, just west of Brisbane, into the soft rocks of the Ipswich Coal-measures. Their progress further west has been checked at Toowoomba by the great sills and flows of basalt extending for some distance N.W. towards the head of the Burnett River. The latter river and the Dawson are fast eating their channels back through the Trias-Jura, and are touching the sediments of the old Cretaceous sea. The Nogoa and Belyando Rivers have broken right across all the old rocks of the plateau of the old Main Divide, so that now around their sources the Main Divide is situated on the Upper Cretaceous, Desert

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[1] Commonwealth Bureau of Meteorology, Melbourne. Physiography of the Proposed Federal Capital Site at Yass-Canberra, Bulletin No.6, p. 8.

[2] This Society's Journal, Vol. xliv, pp. 420 - 480.

[3] Lecture Reported in *Brisbane Telegraph*, 22/5/94.

Sandstone, rocks. Further north in the Cairns District a portion of what was perhaps the original old Divide still survives. In this case heavy crust foundering has all but completely effaced the old eastward flowing river system, leaving so narrow a strip of eastern watershed as to make it impossible for any great rivers to gather, in the ten miles which intervene between the crest of the present Main Divide and the ocean.

It seems strange that the very powerful lines of upheaval of New Guinea running about E.S.E. and W.N.W. have left so little impression upon the tectonic plan of Australia. Possibly the W.N.W. to E.S.E. trend of the schists of the Cape River Gold Field is due to these New Guinea pressure lines, as well as the N. to S. tilt of the Cretaceous Basin and tilt of the Ordovician rocks near the Victoria River in Northern Territory.

New Guinea.—Brief reference will suffice for what is known as to the tectonic lines of New Guinea. At Port Moresby Mr. A. Gibb Maitland[1] found strata formed of sandy limestones and calcareous shales with flints. These contained a *Voluta* which Mr. C. S. Wilkinson, the late Government Geologist of N. S. Wales, considered to be of Miocene or Eocene Age. The Rev. J. E. Tenison-Woods considered the formation to be Pliocene. Lithologically the material somewhat resembles that of the Eocene beds of South Australia, which is also characterised by the presence of flints. The strata are steeply inclined, often vertical, the dip generally is E.N.E. to E. 30° N., at 30 – 55°. Meridional strikes with vertical dips are also recorded. At Yule Island the dip is N. 40° E. at 20 – 30°. At Ware (Teste) Island the limestones are folded on N. and S. axes. At the island of Einauro (Cette) the dip is W. by N. at 50°. In a recent letter Dr. W. G. Woolnough, informs me that he thinks, as the result of a personal examination of the beds, that the pressure came from the north. Dr. Lorentz[1] has referred to limestones discovered by himself in the Wilhelmina Range as of Cretaceous Age. He calls them *Alveolina* limstones. They have been uplifted to over 14,000 feet above sea level.

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[1] Geological Observations in British New Guinea in 1891.

A good account of the geological structure of German New Guinea is given by P. Steph. Richarz.[2] A further account is given by P. Reiber.[3] He gives a section of the Cretaceous rocks of the Torricelligebirge. These dip N.N.W. at 80 – 85°. Richartz considers that the Upper Cretaceous rocks participated in the folding. Beneath the Cretaceous rocks are crystalline schists. In the Ortzengebirge west of the Finisterregebirge, these strike N.W. and S.E. dipping at 70 – 80°, and above the Port Moresby beds are newer sediments, including recently raised reef, ranging up to 2000 feet above sea-level. The Mt. Victory volcano is still active. Thus in New Guinea we see Pre-Cretaceous schistose rocks with N.W. to S.E. trends. These are followed by much folded and greatly elevated Cretaceous rocks, the W.N.W. and E.S.E. directions predominating. These in turn have been succeeded by the Tertiary Port Moresby Beds which have been violently disturbed and uplifted in Post-Eocene, possibly Post-Miocene time. In this later series some northerly to north-westerly lines cross the older lines of folding in the schists and Cretaceous rocks.

Summary of the Tectonic Movements.

In the present imperfect state of our knowledge, the sequence of events in the building of Australia may be briefly outlined as follows :—

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[1] Geogr. Jour., Vol. XXXVII, 1910, p. 496.

[2] Neues Jahr. für Min. Geol. u. Pal., XXIX, Beilage Band, Zweites Heft Stuttgart 1910. Der geologische Bau von Kaiser Wilhelm's Land nach dem heuteren Stand unseres Wissens.

[3] *Ibid.*, XXIX Band, Zweites Heft 1911.

Pre-Cambrian.—In Pre-Cambrian time the rocks of that age in West Australia were folded in the form of an open inverted S, thus Ƨ. In South Australia from Kangaroo Island to Broken Hill the Pre-Cambrian rocks are folded on the pattern of a normal but very open S. At the southern part the overthrusting is to the N.W. and W., in the northern to the S.E. and E. Still further north virgation takes place. In central Australia, at the Musgrave and MacDonnel Ranges, the folding is nearly E. and W. with a tendency in the Musgrave to overfold northwards, and in the MacDonnel Range southwards. In West Australia the direction of folding in the southern part of the reversed S is towards the W. and W.S.W., and in the northern portion partly to the N.E., partly to S.W.

In Tasmania N.N.W. trends predominate, and there appears to be a virgation of the folds, from between N.N.W. to a little E. of N., but this does not become strongly accentuated until Post-Silurian time. The Tasman folds thus form a V. In the Northern Territory the folds run a little W. of N. and E. of S. In the Kimberley District of West Australia they form an arc, the convexity of which is directed southwards.

The *Cambro-Ordovician* rocks are strongly unconformable to the Pre-Cambrian, but in Tasmania and Victoria they appear to have been folded sympathetically with the latter. In the Mount Lofty and Yorke Peninsula areas of South Australia the folds of Cambrian and Pre-Cambrian rocks closely agree, but to the N. of Lake Torrens and S.W. of Lake Eyre there is considerable divergence between the Cambrian and Pre-Cambrian trends, the former inclining to meridional, and the latter to nearly E. and W. lines. The Cambrian Divide lay S. or S.E. of Adelaide in the direction of Jeffreys Deep, the quarter from which moved the ice which produced the vast boulder clays and erratics of the Lower Cambrian of South Australia. In Northern Territory the Cambrian strata are folded and faulted on N.W. to S.E. lines, while the Ordovician rocks are tilted in a S.W. to S. direction.

In *Silurian* time the west-Tasmanian, the Melbourne Lilydale and other basins in Victoria were folded on N.N.W. lines. In the Monaro-Bathurst Tableland of New South Wales the folds strike mostly W. of N. and E. of S., without pronounced overfolding. In the Forbes and Cobar areas the folds swing around to E. of N. and W. of S., conforming more to the Broken Hill lines. At Chillagoe the Silurian strata are folded on E.S.E. to W.N.W. lines.

In *Devonian* time, in the Victorian areas, there is a slight tendency for the folds to fan out or virgate north of the Tasmanian V. On the upper Murrumbidgee near Burrinjuck, they strike north north-westerly, and are uncomformable to the Silurian strata though folded on the same lines, the folding being from W. to E. At Yalwal they strike N. by E. and S. by W. Along the S.W. portion of the Blue Mountain area of New South Wales the Devonian rocks are folded sympathetically with the main axis of the trough of the great coal-field. There is a tendency for these strata to be overfolded inwards towards the centre of the trough. In the New England area the Devonian rocks still preserve a N.N.W. to N. 30° W. strike with a dip towards the trough of the coal basin. In the Burdekin Basin of Queensland the Middle Devonian rocks are folded on north-easterly lines. In the Ord River region of the Kimberley District of West Australia they describe an arc with its convexity directed southwards.

Carboniferous.—In Victoria, in the Avon and Mansfield districts the rocks are folded on N.W. to S.E. lines. In the Grampians area the strike is more meridional. In New South Wales the Carboniferous rocks form a selvage to the

Permo-Carboniferous Basin striking at first N. by W. then bending northwards into a N. 30° W. direction. They too dip in towards the trough of the Permo-Carboniferous Basin. In Queensland the Star Beds of this age build a large portion of the old Main Divide, and their folds curve mostly in sympathy with the coast line. Immense intrusions of serpentine, like those of Marlborough N. of Rockhampton in Queensland, Nundle to Bingara in New South Wales, the Wellington area in Victoria, the serpentine regions in N.W. of Tasmania, etc., took place during this period.

Permo-Carboniferous.—In Tasmania the open end of the V became filled with Permo-Carboniferous sediments. In Victoria and South Australia the earliest strata of this age were formed by ice moving from a general southerly direction, from the old highland Divide which seems to have still survived since Cambrian times, lying considerably south of Kangaroo Island and south of part, at all events, of Tasmania. During this period one of the greatest warps of which we have record in the Australian region in Palæozoic time developed from near Sydney as the centre of the trough, N.N.W. into Queensland, as least as far as Townsville, and probably still further north under what is now the region of the Great Barrier Reef. At this time Eastern Australia was probably, from New England to Townsville, isolated from the portion lying further to the west, first by the Permo-Carboniferous sea, and later by the lakes and swamps of that period. A large portion of Northern Territory, the great desert south of Kimberley in West Australia from near North-west Cape in the north to the Collie Coal-field in the South, was overspread with Permo-Carboniferous marine, or glacial, or swamp sediments. With the intrusions of granite in Victoria, Tasmania, New South Wales and Queensland, the new trend lines of the modern Main Divide were outlined, and in Victoria a strong east and west warp became developed, while in Bathurst-Monaro, and New England, northerly to north north-easterly trends crossed the older north north-westerly trends. The Queensland Divide was at this time probably very close to the Queensland east coast line.

In *Trias-Jura* time great lakes isolated the New England area from the southern end of the old Main Divide near Brisbane, and a prolonged subsidence set in over the region between Brisbane and Lake Eyre, and to the south of the rising Main Divide of Victoria, which had now tilted backwards the glacial beds of Permo-Carboniferous age towards the old, now destroyed Divide far south. (See Fig. 6 *b*.) The Wannon-Otway-Gippsland sediments were laid down in a trough trending east and west, the southern portion extending far up into the V of Tasmania.

In *Cretaceous* time a great sagging continued of the region between Lake Eyre and Roma, as well as on a meridional direction from midway between these points and the Gulf of Carpentaria. The epicontinental sea of the Cretaceous transgression may have completely severed eastern Australia from western from the Gulf of Carpentaria, viâ Lake Eyre, to the head of the great Australian Bight. In Tasmania the further sagging of the old Trias Jura Basin was accompanied by the extrusion on its southern margin of immense sheets of quartz-dolerite. The Cretaceous transgression also submerged a little of the northern part of Northern Territory and an extensive but narrow strip along the west coast of West Australia.

In *Cainozoic* time warping ceased at the northern and central portions of what is now the largest artesian basin in the world, the Cretaceous Basin, from the Gulf of Carpentaria towards Lake Eyre. Further south downward warping submerged much of the southern portion of Victoria, the north-west coast of Tasmania, the south coast of South Australia, and the coastal areas of the great Australian Bight for some distance inland as far west as Cape Arid. Epeirogenic uplift followed. This in east Australia took the form of a gentle warp trending east and west in Victoria, and through New South Wales and Queensland trending parallel with the coast and continental shelf. A new continental shelf was formed across the old gulf of the Permo-Carboniferous Basin in New South Wales. This uplift in east Australia approximately compensated for the downward warping of the great Cretaceous Basin. It ranges from 3,000 feet or 4,000 feet in Queensland to about the same amount in most parts of east New South Wales and of Victoria, attaining its maximum at Mount Kosciusko, 7,300 feet, at the knotting point between the meridional and east and west trends of the great warp.

In South Australia the Mount Lofty and Flinders peneplain was elevated from 2,000 to 3,000 feet above sea-level. In West Australia the vast peneplains are raised from 1,000 to 2,000 feet above sea-level. The determination of the marine fossils (Eocene ?) which overlie this peneplain at Lake Cowan, is of prime importance for the elucidation of the Cainozoic physiography of Australia. Basic volcanic eruptions followed approximately the trend of the warp of the eastern Main Divide. The outflow of basalt was specially heavy in Victoria. The distribution of the alkaline Cainozoic lavas also mark important trend lines in eastern Australia. The photograph of the relief model, (*Plate 1*) shows the trend of the three great volcanic piles of the Canobolas, the Warrumbungles, and the Nandewar mountains. This upward warping was accompanied by heavy inbreaks and foundering of the crust. This is especially marked all along the region of the great Barrier Reef with its archipelago of 'horst' islands of granite, slate, limestone, etc. Nearly the whole of the eastern watershed of the old Divide to the east of Cairns was hereby sunk beneath the sea, leaving merely the sources of the rivers perched high up on the top side of the fault scarp as is the case with the Barron River at the Barron Falls. Profound fractures like those of Broadsound and Curtis Island are ample proof of the heavy crust foundering in this area. The Snowy-Murrumbidgee Rift, and the faults on either side of the Main Divide in New South Wales and Victoria, on the whole tend to throw down the crust on either side of the main axis of elevation. The fact that the old trough of the great coal-field, so long a sinking region, was warped up before the end of Tertiary time, suggests, that, on the isostatic theory of crustal equilibrium, compensation had by this time been established. At the same time the fact must not be overlooked that in Post-Tertiary time the dominant movement along the east coast of Australia has been one of submergence rather than emergence, the submergence amounting to fully 200 feet. Bass Strait was formed by further sag of the E. to W. trough, and development of the Bacchus Marsh and Point Nepean etc. E. to W. faults.

Another great subsidence area developed itself west of the Mount Lofty Range near Adelaide, trending northwards through St. Vincent and Spencer Gulfs to the Lakes Torrens and Eyre regions. This downward warping in the Lake Eyre neighbourhood was probably preceded by a slight tilt of the Cretaceous basin from N. to S., which started the Darling River on its S.W. course: in Cretaceous time the drainage from the N.W. part of New South Wales had gone to the N.W. The 'boathook' junction of the Macquarie, Castlereagh etc. rivers with the Darling is proof of this reversal of the drainage in Post-Cretaceous time.

The interesting case recorded by Mr. Charles Hedley[1] of an extensive change in the position of the Continental

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[1] Proc. Linn. Soc. N.S. Wales, Vol. xxxvi, pt. 1, pp. 17 and 18.

Shelf off Breaksea Spit at the north end of Fraser Island, is probably due, in the opinion of Captain Sharp and myself, to excavation of the sea floor by a powerful marine current. The chart published by Mr. Hedley (*op. cit.* p. 18) shows that the bottom has deepened between the years 1870 and 1904, by no less an amount than 200 fathoms. As far as I am aware no earthquake shocks have been recorded from this region. This makes it improbable that the change of depth is due to bodily crustal re-adjustment. On the other hand the earthquake shocks which from time to time visit the Adelaide region, the Bass Strait area and the Kosciusko area show that adjustment of the earth's crust is still going on at those localities. Recent observations by the Rev. E. F. Pigot, S.J., etc., at Riverview Observatory, Sydney, show that the chief earthquake shocks to which the east coast of Australia is subject, come from deeps in the Tasman Sea, such as Carpenter's Deep and Thomson's Deep.

Conclusions.—The following deductions from the study of the structure of the Australian Continent are only tentative:—1. That Australia, in late Cainozoic time, was larger than at present. It has lost in area peripherally through collapse of marginal segments under gravitational pull.

2. That orogenic movement has affected Australia up to near the end of the Palæozoic Era.

3. That this orogenic movement took the form largely of S-shaped spirals, indicating a tendency of the earth's crust to fold itself in two directions making a wide angle with one another. The dominant direction of the fold lines seems to be about N. by W. to N.N.W., with a tendency on the whole to an overfolding to the west. These meet, mostly in 'syntaxis,' in places in 'linking,' other trend lines directed more E. and W. This spiral arrangement of the trend lines cannot reasonably be correlated with the shape

or distribution of masses of intrusive rock, but is probable evidence of the great predominance of peripheral over radial contraction of the earth's surface.

4. The most extensive granite intrusions which have so much controlled the development of the present Main Divide of Eastern Australia group themselves in time around the Permo-Carboniferous glacial epoch. That epoch was evidently a very critical time in folding, faulting injection of batholiths, and mountain building.

5. Since the close of Palæozoic time Australia has been subjected to broad warps, but not to true folding, except in the direction of New Guinea, where Cretaceous, and even early Tertiary strata are highly folded. New Guinea is thus a new fold region: and even in Australia tectonic movements are newer as New Guinea is approached.

6. In the neighbourhood of large sag basins basic rocks have been erupted, as in the case of the quartz-dolerite (quartz-diabase) sills and dykes of Tasmania, the basalts of the Great Valley of Victoria and the serpentine belt of New England.

7. At least one important basin which has been an area of subsidence for several geological periods, and therefore probably has been an area where gravity has been in excess, has ceased to subside, and has taken part in the upward warping of Eastern Australia in late Tertiary time. On the isostatic theory of crustal equilibrium this would imply that in such an area (as the central coal basin of New South Wales) compensation has now been attained. This may also imply that an extra heavy area, (where gravity is in excess) may eventually become an area of mean density. The rift valley of South Australia from near Adelaide to Lake Eyre is perhaps still subsiding. Bass Strait, and the Snowy-Murrumbidgee rift valley are also probably still subsiding. It would be of considerable scientific interest to have an

accurate gravity survey made across the rift valley of South Australia, across the islands of Bass Strait, and across the islands of Torres Straits and the mainland. The Government Astronomer at Melbourne, Mr. Baracchi, has the necessary instruments for such a survey.

8. While, as already stated, the dominant crust creep in Australia has been westerly, there has also been a tendency, in accordance with the principle enunciated by Suess, for subsidence areas to be overthrust, or, perhaps, as others state it, for the subsidence areas to underthrust adjacent regions, or for overthrusting above and underthrusting beneath.

9. The wide gaps in our knowledge of the trend lines of Australia emphasize the urgent need for a vastly extended series of observations, both on land and sea, before any satisfactory theory can be advanced as to the plan upon which this island continent has been built.[1]

Acknowledgments.—In addition to those whose help has already been acknowledged at the beginning of this address, I desire to express my gratitude to Mr. W. S. Dun for numerous references, and to Dr. W. G. Woolnough, Messrs. Leo A. Cotton, B.Sc., W. R. Browne, B.Sc., and A. B. Walkom, B.Sc., for assistance in correlating trend lines. Further I am much indebted to Messrs. E. C. Andrews, B.A., C. Hedley, and C. A. Süssmilch, F.G.S., for much useful information in the preparation of the relief model forming *Plates 1* and *3*.

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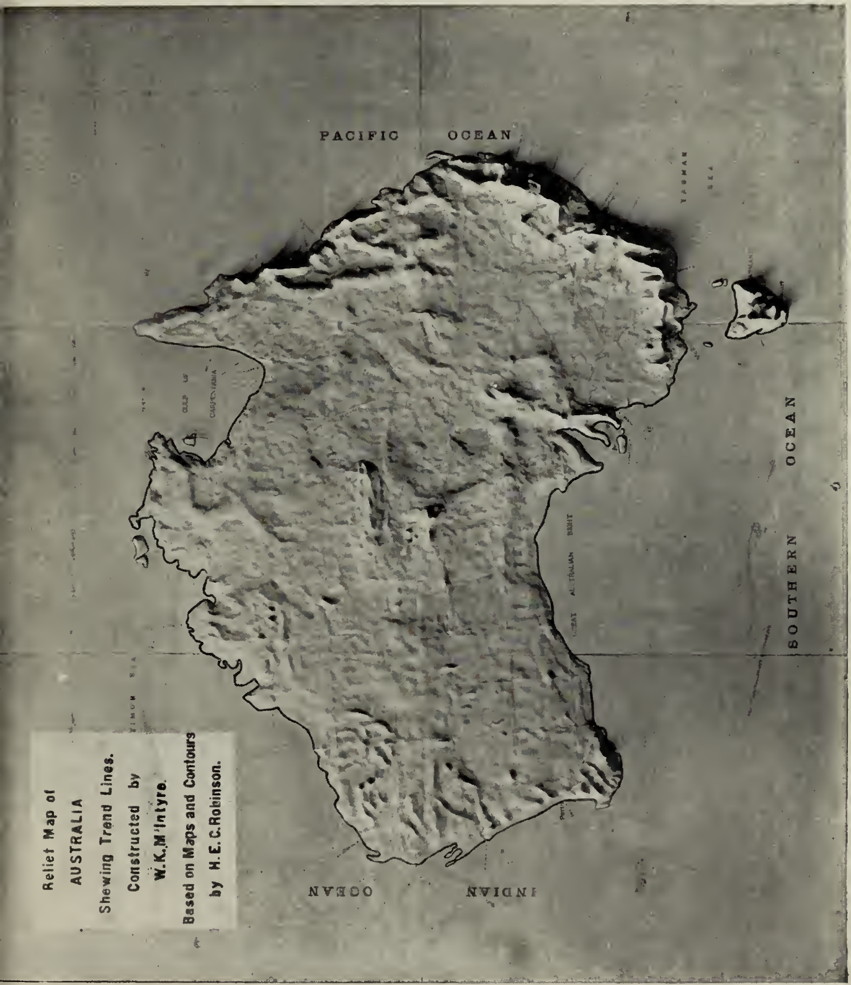
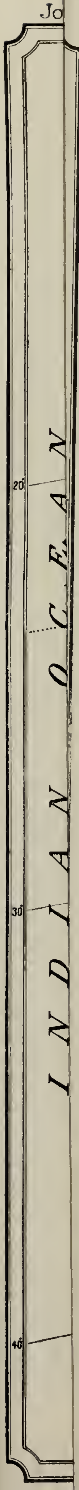
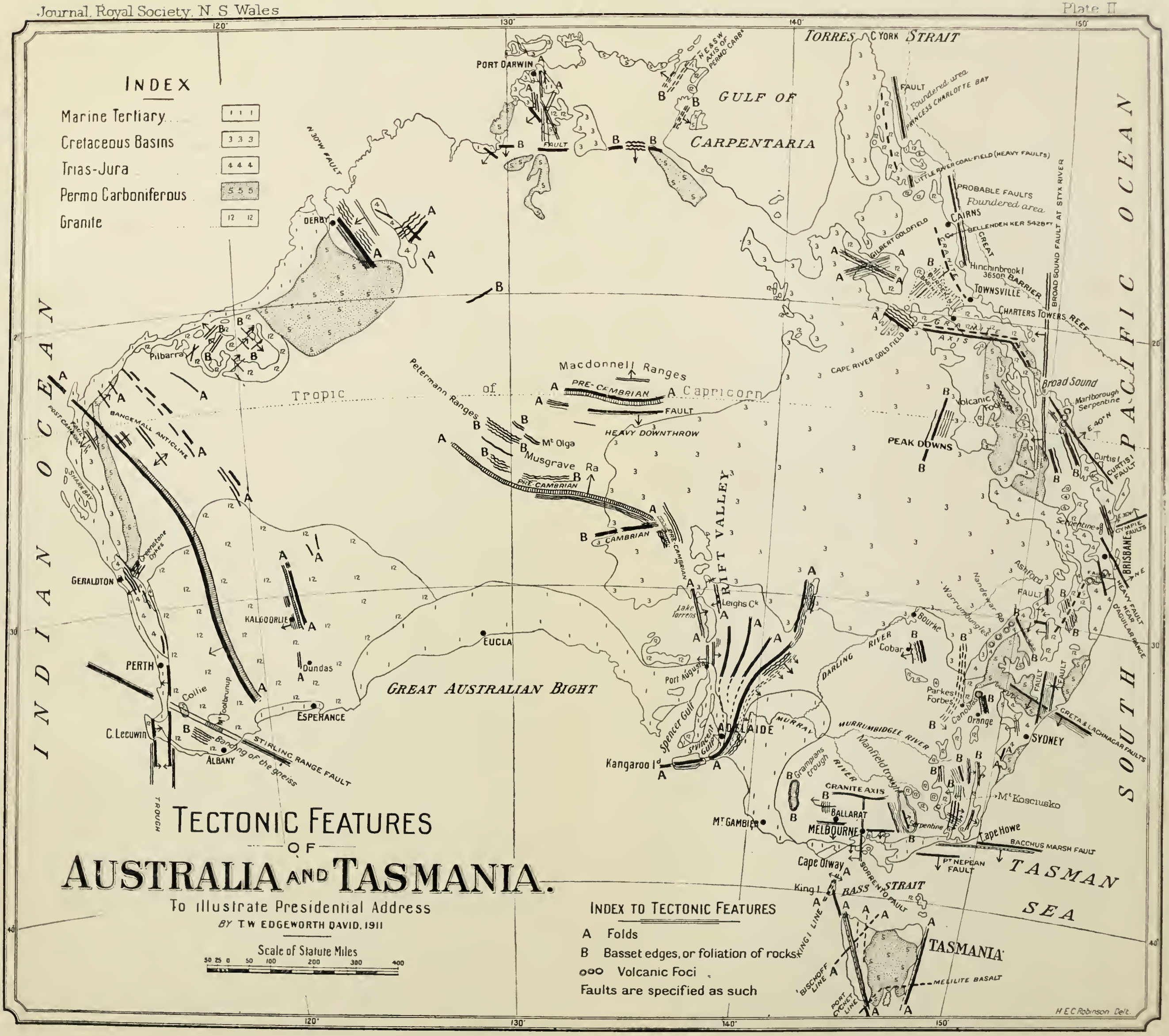
[1] Subsequent to the reading of the above address, the following valuable papers have been published, containing much additional information on the evolution of Australia :—"Physiography of Eastern Australia," by T. Griffith Taylor, B.Sc., B.E., B.A., F.G.S., Commonwealth Bureau of Meteorology, Melbourne, Bulletin 8, May, 1911. An able summary of trend lines and earth movements in areas adjacent to Australia is given by Professor P. Marshall, M.A., D.Sc., F.G.S., Rept. Austr. Assoc. Adv. Sci., Brisbane, 1910. "Ocean Contours and Earth Movements in the South West Pacific," pp. 432 - 449, with four maps.



Relief Map of
AUSTRALIA
Shewing Trend Lines.
Constructed by
W.K.M'Intyre.
Based on Maps and Contours
by H.E.C.Robinson.

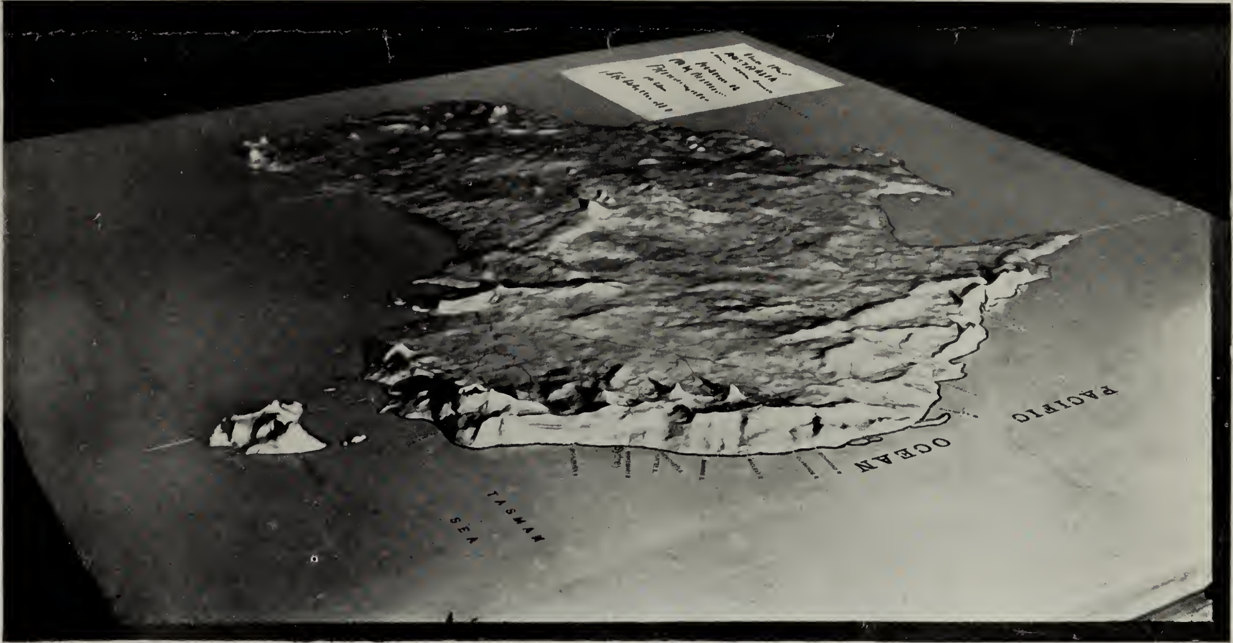

Jo
20°
30°
40°
INDIAN OCEAN



TECTONIC FEATURES OF AUSTRALIA AND TASMANIA.

To illustrate Presidential Address

BY T. W. EDGEWORTH DAVID, 1911



Relief model of Australia and Tasmania by W. K. McIntyre, showing the 'horst' of Tasmania to left of the fault trough of Bass Strait, and Mount Kosciusko at the knotting point of the N. and S. and E. and W. trend lines; one inch to the right of Kosciusko is the Hunter 'Geocol' with the sharp peak of the Warrumbungle Volcanoes behind it, and to the right again the second sharp peak indicates the Nandewar Volcanoes. On the extreme right, is the steep-to coast near Cairns. The Mount Lofty Ranges show up on the near side of St. Vincent's Gulf, with Mount Woodroffe in the middle distance beyond. On the left, in far distance, are the Stirling Ranges.

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